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This work documents the BALLOT2 computer program which may be used to compute the in-bore or balloting motion of a projectile launched in a stationary smooth gun tube. The term "smooth gun tube" means that the gun tube has straight rifling only or no rifling at all. The presentations include all the main equations, the program symbols or codes, the flowcharts, the preparation of the input data, the output of computation results, the operation of the program, and the program usage.

(cont)

20. ABSTRACT (cont)

The program may compute the effects of eccentricity of projectile c.g., axial c.g. location, rotating band properties, projectile dimensions, initial projectile position, bore diameter, friction forces, air resistance, etc. The results of computations are arranged to be printed out in tabular form, plotted in figures, and recorded on a magnetic tape. An example is included to show the data arrangement and the computed results.

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BALLOT 2 - A COMPUTER PROGRAM TO ANALYZE THE IN-BORE MOTION OF A PROJECTILE LAUNCHED IN A STATIONARY SMOOTH GUN TUBE

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INTRODUCTION

The in-bore motion (balloting or transverse motion) of a projectile affects the accuracy, performance, and structural integrity of the projectile, the gun tube, and associated devices. Consequently, it is an important factor which the designer of a projectile or gun system needs to consider.

Extensive investigations of the in-bore motion have been conducted (ref 1 through 5). Equations of motion of a projectile launched in a gun tube have been formulated and many projectiles have been analyzed. However, the past work emphasized only the formulation of the problems and the computations for several projectiles, while little attention was paid to the documentation of the computer programs used. To facilitate future analysis and to aid the user of the computer program, the computer programs listed below will be documented:

- BALLOT. This program analyzes the in-bore motion (balloting or transverse motion) of a projectile launched in a stationary gun tube with constant twist rifling.

- BALLOT2. This program computes the in-bore motion of a projectile launched in a stationary smooth gun tube. This type of gun tube has straight rifling or no rifling.

- BALLOT3. This program analyzes the in-bore motion of a projectile launched in a transversely vibrating smooth gun tube with the breech end fixed. The gun tube has straight rifling or no rifling.

- BALLOT4. This program calculates the in-bore motion of a projectile tube with the breech end fixed. The gun tube has constant twist rifling.

This report deals with the program BALLOT2. The other programs are to be documented separately in the future if necessary. BALLOT2 is intended to facilitate the investigation of the in-bore motion of a projectile launched in a smooth gun tube. The term "smooth gun tube" means that the gun tube has straight rifling only or no rifling at all.

This report documents the main equations, the program symbols or codes, the flowcharts, the preparation of the input data, the output of results, and the operation of the program. A sample computation is included to show the data preparation and the results in tables and figures.

This program is coded in the FORTRAN IV computer language. It will run on CDC 6000 series computers and requires approximately 120000_8 of core storage.

This is the first version of the program. Some of the statements are not in their simplest forms. In order to make the program more easily understood, reader's comments are cordially welcome to guide the future refinement of this program.

THEORY OF ANALYSIS

The computer program BALLOT2 analyzes the in-bore motion of a projectile launched in a smooth stationary gun tube. The mathematical modeling of the problem is based on the plane motion approach. The details of the mathematical modeling are reported separately (ref 6) and not repeated here except for the following descriptions included to aid the user to understand the program.

When a projectile is launched in a smooth stationary gun tube, there is no axial spin of the projectile or the spin is very small and therefore may be ignored. The forces acting on the projectile are in the plane containing the gun tube axis and the c.g. of the projectile, except the gravity force. The effect of the gravity force outside this plane is small and may be ignored. Thus the projectile may be considered to move in this plane, and the plane motion approach is permissible to model the motion of the projectile.

The plane of the motion is represented by the x-y plane (fig. 1). The x-axis is directed along the center line of the gun tube and the y-axis is perpendicular to the gun tube axis and points upward. The origin of this coordinate system is located at the initial intersection of the gun tube axis and the mid-section of the rotating band (or obturator). The projectile's c.g. is in the x-y plane, which may be vertical or not, depending on the inclination, α, of the gun tube and the angle, β, which the x-y plane makes with a vertical plane. The z-axis is determined according to the right-handed Cartesian coordinate system convention.

The forces acting on the projectile (fig. 2) are the base pressure, the contact forces and the frictional forces due to the projectile-gun tube interaction at both the rotating band and the bourrelet, the gravity force, and the aerodynamic forces which resist the motion of the projectile. The gun tube-rotating band contact pressure acting on the rotating band is considered to be a uniform contact pressure, P_o, and an unbalanced normal force resultant, N_o, acting at the maximum deformation point of contact of the rotating band. The base pressure is assumed to act uniformly at the projectile base and the rear side of the rotating band. The gas leakage is ignored. There is a resisting moment at the rotating band which resists the tranverse rotation of the projectile.

The equations of motion for the translation and rotation of the projectile are derived from the plane dynamics principles and the theory of elasticity as follows (ref 6):

$$m\ddot{\chi} = \pi R^2 p - 2\pi\mu_o W R p_o - \frac{V_o}{|V_o|}\mu_o k_o|\delta_o|$$

$$- mg \sin\alpha \frac{V_b}{|V_b|}\mu_b k_b|\delta_b| - \frac{\pi}{2} C_D \rho R^2 \dot{\chi}^2 \qquad (1a)$$

$$m\ddot{y} = \pi R^2 p \tan\theta + k_o\delta_o - mg\cos\alpha\cos\beta$$

$$+ k_b\delta_b + \frac{\pi}{2}\frac{\theta}{|\theta|} C_L \rho R^2 \dot{\chi}^2 \qquad (1b)$$

$$
\begin{aligned}
I\ddot{\theta} = {} & \pi R^2 p \sec\theta\,(y \sec\theta - s\tan\theta) - 2\pi\mu_o W R p_o y \\
& + k_o \left(\delta_o \tan\theta - \frac{V_o}{|V_o|}\,\mu_o |\delta_o|\right)\left(y + \frac{\delta_o}{|\delta_o|} R\right) \\
& - k_o \delta_o\, \ell \sec\theta - C_m \theta \\
& + k_b \left(\delta_b \tan\theta - \frac{V_o}{|V_o|}\,\mu_b |\delta_b|\right)\left(y + \frac{\delta_b}{|\delta_b|} R\right) \\
& + k_b h\, \delta_b \sec\theta \\
& + \frac{\pi}{2}\rho R^2 \dot{\chi}^2 \left\{\frac{\theta}{|\theta|}\left[C_L\,(a\cos\theta + \varepsilon\sin\theta) + C_{Mac} C\right]\right. \\
& \left. + C_D\,(a\sin\theta - \varepsilon\cos\theta)\right\}
\end{aligned}
\tag{1c}
$$

$$
\delta_o = \begin{cases}
R\,(\cos\theta - 1) + \varepsilon\cos\theta + \ell\sin\theta - y \\
\quad \text{when } \varepsilon\cos\theta + \ell\sin\theta - y > R\,(1 - \cos\theta) \\
0 \text{ when } |\varepsilon\cos\theta + \ell\sin\theta - y| \leqslant R\,(1 - \cos\theta) \\
-[R\,(\cos\theta - 1) - (\varepsilon\cos\theta + \ell\sin\theta - y)] \\
\quad \text{when } \varepsilon\cos\theta + \ell\sin\theta - y < -R\,(1 - \cos\theta)
\end{cases}
\tag{1d}
$$

$$
\delta_b = \begin{cases}
r_b \cos\theta - R + \varepsilon\cos\theta - h\sin\theta - y \\
\quad \text{when } \varepsilon\cos - h\sin\theta - y > R - r_b\cos\theta \\
0 \quad \text{when } |\varepsilon\cos\theta - h\sin\theta - y| \leqslant R - r_b\cos\theta \\
\quad \text{or } \chi > \chi_T - h \\
-[r_b\cos\theta - R - (\varepsilon\cos\theta - h\sin\theta - y)] \\
\quad \text{when } \varepsilon\cos\theta - h\sin\theta - y < -[R - r_b\cos\theta)
\end{cases}
\tag{1e}
$$

$$
V_o = \dot{\chi} + \left(y + \frac{\delta_o}{|\delta_o|} R\right)\dot{\theta} \tag{1f}
$$

$$
V_b = \dot{\chi} + \left(y + \frac{\delta_b}{|\delta_b|} R\right)\dot{\theta} \tag{1g}
$$

$$
N_o = k_o \delta_o \tag{1h}
$$

$$
N_b = k_b \delta_b \tag{1i}
$$

where

a	=	Axial distance of projectile c.g. to aerodynamic center (a.c.) where aerodynamic forces act. It is not equal to the free-flight value and it should be determined experimentally under the in-bore motion conditions.
C	=	Reference length for aerodynamic moment computation
C_D, C_L, C_{Mac}	=	Coefficient of aerodynamic drag, lift, moment. It is not equal to the free-flight value and it should be determined experimentally under the in-bore motion conditions.
C_m	=	Angular spring constant for transverse rotation of projectile or moment to turn projectile transversely about rotating band per unit angle
g	=	Gravitational constant
h	=	Axial distance of projectile c.g. to leading edge of bourrelet
I	=	Transverse moment of inertia of projectile about c.g.
k_o, k_b	=	Spring constant of rotating band, bourrelet
ℓ	=	Axial distance of projectile c.g. to rotating band mid-section
m	=	Mass of projectile
N_o, N_b	=	Normal force resultant acting at rotating band, bourrelet
p	=	Base firing pressure per unit area
p_o	=	Gun tube-rotating band uniform contact pressure per unit area
r_b	=	Bourrelet radius
R	=	Bore radius of gun tube
s	=	Axial distance of projectile c.g. to projectile base plane
V_o, V_b	=	Velocity of rotating band, bourrelet contact point at maximum deformation

W	=	Width of rotating band
x, $\dot{x}$, $\ddot{x}$	=	Axial displacement, velocity, acceleration of projectile
x_T	=	Travel of projectile when rotating band exits muzzle
y	=	Normal displacement of projectile c.g.
δ_o, δ_b	=	Maximum normal deflection at rotating band, bourrelet, positive (negative) for lower (upper) side contact
ε	=	Projectile c.g. eccentricity from geometric axis of projectile; positive (negative) when c.g. is above (under) geometrical axis as shown in x-y plane
θ, $\ddot{\theta}$	=	Yaw angle, acceleration of projectile
μ_o, μ_b	=	Frictional coefficient at rotating band, bourrelet
ρ	=	Air density used to compute air resistance or aerodynamic force inside the gun tube

Any standard numerical integration method may be used to solve these equations. The Euler's method and the constant acceleration technique are used in this program. The basic equations used are:

$$\dot{y}_{n+1} = \dot{y}_n + \ddot{y}_n \, \Delta t \tag{2a}$$

$$y_{n+1} = y_n + \dot{y}_n \, \Delta t + \frac{1}{2} \ddot{y}_n \, (\Delta t)^2 \tag{2b}$$

where

y, $\dot{y}$, $\ddot{y}$	=	Displacement, velocity, acceleration
Δt	=	Time step size
n, $n + 1$	=	Subscript to denote time step number

The frictional coefficients, the spring constants and the average gun tube-rotating band uniform contact pressure may be obtained from the experimental data. However, when the experimental data are not available, approximate equations may be used to compute the data. The equations are derived from the principles of elasticity and thin shell theory and are as follows:

$$k_b = \frac{E_b t_b^{\,3}}{0.135 \, r_b^2} \tag{3}$$

$$p_o = E_o \left(r_i^2 - r_e^2\right) \{r_p (r_p - r_i) [(1 - \nu_o) R^2$$
$$+ (1 + \nu_o) r_e^2] - R (R - r_e) [(1 - \nu_o) r_p^2 + (1 + \nu_o) r_e^2] \}$$
$$/ r_e^2 \{ [(1 - \nu_o) R^2 + (1 + \nu_o) r_i^2] [(1 - \nu_o) r_p^2 + (1 + \nu_o) r_e^2]$$
$$- [(1 - \nu_o) R^2 + (1 + \nu_o) r_e^2] [(1 - \nu_o) r_p^2 + (1 + \nu_o) r_i^2] \} \tag{4}$$

where

E_b, E_o	=	Young's modulus of bourrelet, rotating band material
t_b	=	Wall thickness of bourrelet
r_i, r_e	=	Inner, outer radius of rotating band. In case of a rotating band which is fitted on the projectile, the inner radius is equal to the original value before fitting on the projectile.
r_p	=	Radius of rotating band seat of projectile
ν_o	=	Poisson's ratio of rotating band material

The computed uniform contact pressure, p_o, is used for the starting period of projectile motion. Experiments show that the contact pressure decreases as the projectile moves toward the muzzle. A linear relationship between this pressure and the distance to the muzzle is therefore assumed in this program. The ratio of this pressure at the muzzle and at the beginning of projectile motion may be estimated according to known experimental data of similar gun and projectile systems.

The base firing pressure is used in the computation. If the given data is the chamber pressure, it is converted to base pressure according to the following equation (ref 7):

$$\frac{P_c}{P_b} = 1 + \frac{C}{2W_p} - \frac{1}{24\gamma} \left(\frac{C}{W_p}\right)^2$$
$$+ \left(\frac{1}{80\gamma} + \frac{1}{360\gamma^2}\right) \left(\frac{C}{W_p}\right)^3 + \ldots \tag{5}$$

where

P_c	=	Chamber pressure
P_b	=	Base pressure

C = Weight of charge

W_p = Weight of projectile

γ = Ratio of specific heats of propellant gases (its typical value is 1.25 which is used in the present program)

To estimate an intermediate value from two given data pairs, a linear interpolation equation is used in this program. This equation is as follows:

$$y_i = y_n + \frac{y_{n+1} - y_n}{\chi_{n+1} - \chi_n} (\chi_i - \chi_n) \tag{6}$$

where

χ_n, χ_{n+1} = Given χ values at known time or space stations n and n + 1, respectively

y_n, y_{n+1} = Given y values at known time or space stations n and n + 1, respectively

χ_i = Known intermediate value of χ

y_i = Intermediate value of y to be computed

FEATURES OF PROGRAM

The BALLOT2 program computes the in-bore motion of a projectile and the associated forces during the launch period when the projectile is inside a stationary smooth gun tube. The program may compute the effects of the following parameters:

1. Eccentricity of projectile c.g.

2. Axial c.g. location

3. Bourrelet diameter

4. Bourrelet wall thickness

5. Bourrelet band width (length of bourrelet portion having diameter same as bourrelet diameter)

6. Bourrelet location

7. Rotating band diameter

8. Rotating band width

9. Rotating band thickness

10. Rotating band location

11. Length of projectile

12. Weight of projectile

13. Initial position of projectile

14. Bore diameter

15. Travel of projectile or the length of gun tube

16. Inclination of gun tube

17. Friction at the bourrelet

18. Friction at the rotating band

19. Air resistance

20. Magnitude and variation of firing pressure

21. Material properties of projectile

22. State of wear of gun tube

The program requires the input data related to these parameters. The input data may be in either English or metric units of measurement. However, they are converted to English units in the computation. The outputs are expressed in both English and metric units.

The program computes the rotating band gun tube contact pressure and the spring constants at the rotating band and the bourrelet when no experimental data are available.

The input firing pressure may be either base or chamber pressure. If chamber pressure is used, it is converted to base pressure in the program. The input data which are related to the locations of the projectile in the gun tube are expressed in terms of distances to the muzzle. This facilitates the preparation of input data for the investigation of cases including similar gun tubes of different lengths. These distances are converted to those referred to in the initial position of the projectile c.g. in the computation.

The results of the computations are arranged to be printed out in tabular form, plotted in figures, and recorded on a magnetic tape.

OUTLINE OF PROGRAM

The program first reads and then prints the input data cards in original order for data check and future reference. The main input data are later printed in tabular form for easy reference. During the computation, some of the main computed parameters are printed at specific time intervals to provide a check on the state of the computation.

The maximum and minimum values of the results of the computation are printed in tabular form and the detailed outputs of all the main computed quantities are recorded on magnetic tape. This information can also be printed in tables in order of increasing time, if these data are requested. Some of the computed results, such as axial and normal displacements, velocities and accelerations, normal or lateral forces at the rotating band and bourrelet, normal accelerations at axial point F (any desired axial point such as the fuze c.g. location), yaw angles, and air resistance (aerodynamic drag forces) are plotted in curves against time and projectile travel.

The program consists of one main program and seventeen subroutines. The principal functions of the main program and the subroutines are as follows:

1. Main program BALLOT2--Control of input data, computation of projectile motion and forces, and control of output data and figures.

2. Subroutine CLIPV--Determination of an intermediate value of a variable associated with a linearly increased argument according to the linear interpolation principle.

3. Subroutine CMAXMIN--Determination of the extreme values of computed variables and associated time and projectile displacement.

4. Subroutine CRIPV--Determination of an intermediate value of a variable associated with a randomly varied argument according to the linear interpolation principle.

5. Subroutine DATAINP--Input of program data.

6. Subroutine DIPTBL--Printout of input data in original punched card format and in tabular form.

7 Subroutine DTARO--Arrangement of input data pairs in proper order and magnitude to be used in computation.

8. Subroutine DTATBL--Printout of data in tabular form with two data per line.

9. Subroutine FIGCTRL--Control of output figure drawing.

10. Subroutine FGCV3--Curve plotting.

11. Subroutine FGDA3--Preparation of data for curve plotting.

12. Subroutine FGMN3--Determination of maximum and minimum values of axes scales for curve plotting.

13. Subroutine FGPRTCV--Printer curve plotting.

14. Subroutine FGPRTSB--Determination of curve symbols for curve printing.

15. Subroutine FGSCLIR--Computation of proper ratio for figure axes scales.

16. Subroutine FGSTRT--Computation of figure axis scale starting values and units for curve plotting.

17. Subroutine OPDTA--Printout of all computed results in order of increasing time.

18. Subroutine OPTBL--Printout of maximum, minimum, and muzzle values of computed results.

19. Subroutines SCALE, AXIS, LINE, SYMBOL, PLOT, and ASPECT are library plotting subroutines. They are contained in the FORTRAN extended library of the computer. Other subroutines not mentioned here but used in the program are all library subroutines.

The outline flowchart of the program is shown in figure 3.

Detailed descriptions of the main program and subroutines are presented in the following sections. Descriptions and definitions of program symbols or codes of the main variables or parameters and flowcharts are included in each section. The intermediate or dummy symbols used to make the program easier to follow and the symbols for subscripts or control transfer are not discussed.

The transfer of data among the main program and subroutines is through labeled common blocks which are listed in table 1.

A discussion of the main program and subroutines follows. Note that the various units shown are for reference only. They may be changed depending on the input data specification or control. (See input data coding, page 15.)

Main Program BALLOT2

Computation is performed in the main program BALLOT2. It uses different subroutines to obtain input data, print computed results, and plot output figures. The definitions of program symbols are presented in table 2.

The flowchart of the main program is shown in figure 4.

Subroutine CLIPV

This subroutine is used to find the intermediate value, YO, of the variable, YD, corresponding to the known value, XO, of the linearly increased argument XD, based on the principle of linear interpolation. There are ND pairs of known data of XD and YD. The known value, XO, of XD determines the control number, N, which in turn determines the value of the slope, SLP, of the XD-YD curve of the computation. The value, YO, is then computed using the values of XO, XD, and YD. The value of SLP is saved or recomputed for the next computation, depending on the values of XO, XD, and YD. The computation is performed according to equation 6. The program symbols and their descriptions are listed in table 3 and the flowchart is shown in figure 5.

Subroutine CMAXMIN

Subroutine CMAXMIN is used to determine the maximum and minimum values of a computed variable, X for example, and the related time and axial projectile displacement. These values are determined by comparing all computed values during the computation process.

The program symbols for the various quantities are listed in table 4 and the flowchart is shown in figure 6.

Subroutine CRIPV

Subroutine CRIPV determines the intermediate value, YO, of YD corresponding to the known value, XO, of the randomly varied argument, XD, based on the principle of linear interpolation. It is similar to subroutine CLIPV except that the independent variable is now varied randomly. The descriptions and definitions of symbols used are the same as those of subroutine CLIPV. The program stops the computation when the known intermediate value, XO, is larger than the given maximum value of XD. An adjustment of the time step size may be necessary to rerun the program again. The flowchart of subroutine CRIPV is shown in figure 7.

Subroutine DATAINP

Subroutine DATAINP reads, writes, and converts input data. Input data may be in either English or metric units; however, in processing the computation, they are converted and processed in English units. The output data are in both English and metric units. Details of input data preparation are described in Input Data Coding (page 15).

Most of the program symbols used in this subroutine are the same as those used in the main program and have been listed in table 2. The additional program symbols not presented in table 2 are in table 5. The flowchart of this subroutine is shown in figure 8.

Subroutine DIPTBL

This subroutine prints the input and initial data in tabular form. First it prints the title of the table, and then it calls subroutine DTATBL to convert the data to proper units and print two data per line of the table. The program symbols are the same as those mentioned in the main program and subroutine DATAINP except for a few additional symbols. These symbols are easy to understand and are not discussed here. The flowchart of this subroutine is shown in figure 9.

Subroutine DTARO

Subroutine DTARO reverses the order of X,Y data pairs and changes the magnitude of Y and the reference point or origin of X, if desired. For example, the muzzle distance-gun tube diameter data may be converted to the breech end distance-gun tube radius data. The program symbols for the various main quantities are listed in table 6; the flowchart is shown in figure 10.

Subroutine DTATBL

Subroutine DTATBL prints the given data pairs in tabular form with two data per line. The given data pairs are multiplied with proper conversion ratios so they may be printed out in both metric and English units. The descriptions and definitions of additional program symbols are presented in table 7. The flowchart is shown in figure 11.

Subroutine FIGCTRL

Subroutine FIGCTRL controls the plotting of the computed projectile motion and forces against time and projectile travel, respectively. The plotted figures portray the axial and normal displacements, velocities, and accelerations; the yaw angles, velocities, and accelerations; the normal or lateral forces at the rotating band and the bourrelet, respectively; the normal accelerations at a special axial point, say point F, where the acceleration information is required; and the aerodynamic drag forces. All figures are plotted in metric units. Control numbers are provided to plot the desired figures and plot the figures against time or projectile travel, respectively. The main program symbols are the same as those mentioned in the main program and subroutine DATAINP. Additional program symbols are listed in table 8 and the flowchart is shown in figure 12.

Subroutine FGCV3

Subroutine FGCV3 plots one to three curves in one graph with data prepared from subroutines FGDA3 and FGMN3. It also writes the figure titles, subtitles,

and labels. Additional program symbols are listed in table 9. The flowchart is shown in figure 13.

Subroutine FGDA3

This subroutine reads and converts the tape recorded data to suitable values for the plotting of one to three curves. The data tape is labeled tape 1. Additional program symbols are listed in table 10, and the flowchart is shown in figure 14.

Subroutine FGMN3

This subroutine determines the maximum and minimum values of axis scales for the plotting of one to three curves in one graph and prepares related axis labels. These values are determined according to input data or the computed results in the program. Additional program symbols used in this subroutine are listed in table 11, and the flowchart is shown in figure 15.

Subroutine FGPRTCV

Subroutine FGPRTCV prints one to three curves on output paper and labels them with symbols A, B, and C, respectively. The figure fits the 8 1/2 x 11 in. frame size and is suitable to be included in a report. The additional program symbols are listed in table 12. The simplified flowchart is shown in figure 16.

Subroutine FGPRTSB

Subroutine FGPRTSB determines curve symbols for printer plotting. The symbols for one to three curves are prepared. Additional program symbols are listed in table 13 and the simplified flowchart is shown in figure 17.

Subroutine FGSCLIR

Subroutine FGSCLIR determines a proper integer ratio for figure scales when two or three curves are plotted in one graph. However, the initial computation of this ratio is first done in subroutine FGMN3 and subroutine FGSCLIR refines this ratio when it is larger than 5. The symbol N is first used to represent the originally computed scale ratio in interger form, and later it is assigned to the recomputed ratio. The symbol ND is the originally computed scale in floating point form. The flowchart of this subroutine is shown in figure 18.

Subroutine FGSTRT

Subroutine FGSTRT computes the starting value and units of figure axis for curve plotting. It determines these values according to given maximum and minimum scale values or maximum and minimum values of computed results. The program symbols used in this subroutine are listed in table 14 and the flowchart is shown in figure 19.

Subroutine OPDTA

This subroutine prints all computed data in metric units. It prints these data in order of time and in three tables. The maximum number of recorded data is 600. Less than 600 data points may be printed when the value of NPOPDTA is greater than one. The printer will print every (NPOPDTA)th data from about 600 data points recorded on tape 1. Additional program symbols used in the subroutine are listed in table 15; the flowchart is shown in figure 20.

Subroutine OPTBL

Subroutine OPTBL prints a table of maximum, minimum, and muzzle values of computed results. The data are expressed in both metric and English units. Additional program symbols are used to represent the computed results in different units, but because they are easy to understand in this program, they are not discussed here. The flow chart is shown in figure 21.

PROGRAM OUTPUT

The functions of the main program and various subroutines in printing the output and plotting the curves of computed results have been mentioned in the previous sections. The following presentation is provided to give the user or reader a complete idea of the arrangement of the program output.

The program first prints out the cover page of the output sheets and the title and subtitle of the analysis, and then the date of the computer run is recorded.

The input data deck is printed out card by card in original order so that it is easy to check the input data if such a check is necessary.

The initial projectile position, given initial yaw angle, and computed yaw angle when the bourrelet just contacts the gun tube, are recorded. The computed gun tube-rotating band contact pressure will be printed out if the friction coefficients are given and there is no pressure input data.

The dimensions and physical properties of the projectile and gun tube are printed out in a table, and so is the firing pressure-time data. Similar tables for spring constants or compression test data, contact pressure, tube wear, and aerodynamic coefficients or test data are also printed if there are input data.

When the program starts the computation, the heading: "Intermediate printout of computed values of main quantities vs time" is printed, and the so-called main quantities are printed at specified time intervals (determined by input data). It is useful to check these results when the computation fails to see which parameters are abnormal. The total number of computation cycles and data recorded on magnetic tape are recorded at the end of this table.

At the end of the computation, maximum, minimum, and muzzle values of the main computed results such as linear and angular displacement, velocity and acceleration, and forces are printed out in a table.

Approximately 600 data points of each computed main quantity are recorded on a magnetic tape and may be printed out in three tables if desired.

Finally, the axial and normal displacement, velocity and acceleration, yaw angle and velocity, yaw acceleration, normal acceleration at axial point F, lateral forces at the rotating band and the bourrelet, and aerodynamic drag force curves are printed out against time, or travel, or both. They are also plotted on plain or grided graph paper on a Calcomp plotter. The printer plotting is printed out with one figure per page of computer output paper.

INPUT DATA CODING

Subroutine DTAINP reads and prints input data in original order. The input data may be expressed in either English or metric units. However, in the solution of the problem, they are converted and processed in English units and the output data are in both English and metric units. The following input data cards are necessary to define a problem to be solved by the BALLOT2 program. The simplified diagram of a projectile (fig. 22) indicates the needed dimensions except those of the rotating band which are needed for average gun tube-rotating band contact pressure computations. The input data cards are arranged in the following order:

1. Title card (1 card)

   List TITLEM

   Format (5A10)

Columns	Symbol	Format	Description
1-50	TITLEM	5A10	Title for analysis

2. Subtitle card (1 card)

List TITLES

Format (5A10)

Columns	Symbol	Format	Description
1-50	TITLES	5A10	Supplementary information about this analysis; if no information, leave it blank.

3. Computation and output control card (1 card)

List NIDTBL, NCCK, NOPTBL, NOOPDTA, NPOPDTA, NDAMS, NDARAD

Format (7I10)

Columns	Symbol	Format	Description
1-10	NIDTBL	I10	Printout of input data in tabular form; if = 0 or blank, printout input data; if = 1, no printout.
11-20	NCCK	I10	Printout of some computed values during processing; every (NCCK)th data recorded on magnetic tape is printed out for intermediate check of computations; if = 0 or blank, NCCK is set to be 15 in the program.
21-30	NOPTBL	I10	Printout of maximum, minimum, and muzzle values of computed results in tabular form; if = 0 or blank, printout table; if = 1, no printout.
31-40	NOOPDTA	I10	Number of computed data to be recorded on tape; every (NOOPDTA)th data computed will be recorded. If = 0 or blank, NOOPDTA is set to be such a number that approximately 600 data are recorded.

41-50	NPOPDTA	I10	Number of detailed output to be printed; every (NPOPDTA)th data recorded on tape 1 will be printed out. If = 0 or blank, no printout.
51-60	NDAMS	I10	Units used in projectile and gun tube data; if = 0 or blank, data are expressed in English units; if = 1, metric units.
61-70	NDARAD	I10	Unit for angles; if = 0 or blank, angle is expressed in degrees; if = 1, radians.

4. Time card (1 card)

List TMAX, TSEP, TSLAST

Format (3F10.5)

Columns	Symbol	Format	Description
1-10	TMAX	F10.5	Estimated time duration of computation, ms; computation starts at TIME = 0 and stops at TIME = TMAX or when projectile is out of muzzle; default value = maximum time of firing pressure-time input data.
11-20	TSTEP	F10.5	Time step size for constant step size computation or first step size for uniformly decreased step size computation, ms.
21-30	TSLAST	F10.5	Last step size of uniformly decreased step size computation, ms.

5. Projectile card set (3 cards)

Card A Dimension card

List PROJL, RBX, RBW, RBD, CGX, CGD, CGEL, CGEMT

Format (8F10.5)

Columns	Symbol	Format	Description
1-10	PROJL	F10.5	Length of projectile; in inches if NDAMS = 0 or blank; cm if NDAMS = 1.

11-20	RBX	F10.5	Distance from projectile base to nearest side of rotating band; in inches if NDAMS = 0 or blank; cm if NDAMS = 1.
21-30	RBW	F10.5	Width of rotating band; in inches if NDAMS = 0 or blank; cm if NDAMS = 1.
31-40	RBD	F10.5	Outside diameter of compressed rotating band after projectile is loaded in gun tube; it is equal to or less than bore diameter; in inches if NDAMS = 0 or blank; cm if NDAMS = 1; if = 0 or blank, it is set to be equal to bore diameter in the program.
41-50	CGX	F10.5	Distance from projectile base to c.g.; in inches if NDAMS = 0 or blank; cm if NDAMS = 1.
51-60	CGD	F10.5	Projectile diameter at c.g. section; in inches if NDAMS = 0 or blank; cm if NDAMS = 1. If left blank, it is set to be equal to bourrelet diameter in the program.
61-70	CGEL	F10.5	Projectile c.g. eccentricity in distance from c.g. to projectile axis; in inches if NDAMS = 0 or blank; cm if NDAMS = 1; if left blank, it will be computed from CGEMT in the program.
71-80	CGEMT	F10.5	Projectile c.g. eccentricity in unbalanced moment about projectile axis; in in-oz if NDAMS = 0 or blank; cm-N if NDAMS = 1; if left blank, it will be computed from CGEL in the program.

Card B Dimension card (continued)

List BRTX, BRTW, BRTOD, BRTID, BRTTK, APAX, APFX

Format (7F10.5)

Columns	Symbol	Format	Description
1-10	BRTX	F10.5	Distance from projectile base to bourrelet; in inches if NDAMS = 0 or blank; cm if NDAMS = 1.
11-20	BRTW	F10.5	Width of bourrelet portion having same diameter as bourrelet; in inches if NDAMS = 0 or blank; cm if NDAMS = 0 or blank.
21-30	BRTOD	F10.5	Outside diameter of bourrelet; in inches if NDAMS = 0 or blank; cm if NDAMS = 1.
31-40	BRTID	F10.5	Inside diameter of bourrelet; in inches if NDAMS = 0 or blank; cm if NDAMS = 1. If left blank, it will be computed from outside bourrelet diameter and bourrelet thickness data.
41-50	BRTTK	F10.5	Thickness of projectile wall at bourrelet; in inches if NDAMS = 0 or blank; cm if NDAMS = 1. If left blank, it will be computed from outside and inside bourrelet diameter values in the program.
51-60	APAX	F10.5	Distance from projectile nose to projectile axial point A, where normal acceleration computation is desired; in inches if NDAMS = 0 or blank; cm if NDAMS = 1.
61-70	APFX	F10.5	Distance from projectile nose to projectile axial point F, where normal acceleration computation is desired; in inches if NDAMS = 0 or blank; cm if NDAMS = 1.

Card C Physical property card

List PWT, TMOI

Format (2F10.4)

Columns	Symbol	Format	Description
1-10	PWT	F10.4	Weight of projectile in lb if NDAMS = 0 or blank; kg if NDAMS = 1.

11-20	TMOI	F10.4	Transverse moment of inertia of projectile about center of gravity; in lb-in^2 if NDAMS = 0 or blank; kg-m^2 if NDAMS = 1.

6. Gun tube card (1 card)

List ALPHA, BORED, FPEA, TRAVEL

Format (4F10.5)

Columns	Symbol	Format	Description
1-10	ALPHA	F10.5	Gun tube inclination; in deg if NDRAD = 0 or blank; rad if NDRAD = 1.
11-20	BORED	F10.5	Bore diameter; in inches if NDAMS = 0 or blank; cm if NDAMS = 1.
21-30	FPEA	F10.5	Effective acting area of base pressure; it is used to multiply base pressure to get pressure resultant; in in^2 if NDAMS = 0 or blank; cm^2 if NDAMS = 1.
31-40	TRAVEL	F10.5	Travel of projectile from its initial position to rotating band exit; in inches if NDAMS = 0 or blank; cm if NDAMS = 1.

7. Projectile inclination card (1 card)

List BETA, THETA, THETAR

Format (3F10.5)

Columns	Symbol	Format	Description
1-10	BETA	F10.5	Angle between vertical plane and X-Y plane (or plane containing projectile c.g. and gun tube axis); in deg if NDRAD = 0 or blank; RAD if NDRAD = 1.
11-20	THETA	F10.5	Initial yaw angle (or angle between projectile axis and gun tube axis); in deg if NDRAD = 0 or blank; rad if NDRAD = 1.

21-30	THETAR	F10.5	Computation of yaw angle with bourrelet just contacting gun tube at 6 o'clock position; if = 1, computation will be done in the program and computed value will be used as initial yaw angle in the computation; if = 0 or blank, computation is also done but commputed value will not be used as initial yaw angle.

8. Figure card set (1 to 13 cards)

Card A Figure plotting control card

List NCGDVAA, NCGDVAN, NLF, NAPFA, NAF, NYAWDV, NYAWA, NFGVSX

Format (8I10)

Columns	Symbol	Format	Description
1-10	NCGDVAA	I10	Plot curves of axial c.g. displacement, velocity, and acceleration in one graph; if = 1, curves are plotted; if = 0 or blank, no plot.
11-20	NCGDVAN	I10	Plot curves of normal c.g. displacement, velocity, and acceleration in one graph; if = 1 curves are plotted; if = 0 or blank, no plot.
21-30	NLF	I10	Plot curves of normal forces at bourrelet and rotating band; if = 1, plot curves; if = 0 or blank, no plot.
31-40	NAPFA	I10	Plot curve of normal acceleration at axial point F of projectile; if = 1, plot curve; if = 0 or blank, no plot.
41-50	NAF	I10	Plot curve of aerodynamic drag force; if = 1, plot curve; if = 0 or blank, no plot.
51-60	NYAWDV	I10	Plot curves of yaw angle and velocity; if = 1, plot curves; if = 0 or blank, no plot.

61-70	NYAWA	I10	Plot curve of yaw acceleration; if = 1, plot curve; if = 0 or blank, no plot.
71-80	NFGVSX	I10	Plot curves versus projectile travel; if = 0 or blank, curves are plotted versus time only; if = 1, curves are plotted versus projectile travel in addition to those plotted versus time.

The following cards, B through N, are omitted if no figures are required.

Card B Figure scale card

List MXMN, FGXMAXM, FGTMAX, FGXMAX

Format (I10, 3F10.5)

Columns	Symbol	Format	Description
1-10	MXMN	I10	Determine maximum and minimum values of graph axis scales; if = 0 or blank, scale values will be computed in the program; if = 1, values are entered in following cards C-G.
11-20	FGXMAXM	F10.5	Maximum value of figure displacement axis scale in metric unit; if left blank, it will be computed from FGXMAX value in the program.
21-30	FGTMAX	F10.5	Maximum value of figure time axis scale in ms; if = 0 or blank it will be set to equal to TMAX input value in the program.
31-40	FGXMAX	F10.5	Maximum value of figure projectile travel axis scale in English unit, in; leave blank if FGXMAXM value is entered or if FGXMAXM is to be determined in the program.

If MXMN = 0 in card B, the following cards C through G are omitted.

Card C Horizontal axis scale and unit control card

List FTMAX, FTMIN, FXMAX, FXMIN, UNITMS

Format (5F10.4)

Columns	Symbol	Format	Description
1-10	FTMAX	F10.4	Maximum value of time scale of figure, ms. It overrides similar value entered in card B.
11-20	FTMIN	F10.4	Minimum value of figure time scale, ms.
21-30	FXMAX	F10.4	Maximum value of figure travel axis scale; in inches if UNITMS = 0 or blank; m if UNITMS = 1.
31-40	FXMIN	F10.4	Minimum value of figure travel axis scale; in inches if UNITMS = 0 or blank; m if UNITMS = 1.
41-50	UNITMS	F10.4	Determine units of maximum and minimum values of axis scale; if = 0 or blank, English units are used; if = 1, metric units are used.

Card D Axial displacement, velocity, and acceleration scale card

List FCGADMX, FCGADMN, FCGAVMX, FCGAVMN, FCGAAMX, FCGAAMN

Format (6F10.4)

Columns	Symbol	Format	Description
1-10	FCGADMX	F10.4	Maximum value of projectile axial displacement axis scale; in inches if UNITMS = 0 or blank; m if UNITMS = 1.
11-20	FCGADMN	F10.4	Minimum value of projectile axial displacement axis scale; in inches if UNITMS = 0 or blank; m if UNITMS = 1.
21-30	FCGAVMX	F10.4	Maximum value of projectile axial velocity axis scale; in ft/s if UNITMS = 0 or blank; m/s if UNITMS = 1.
31-40	FCGAVMN	F10.4	Minimum value of projectile axial velocity axis scale; in ft/s if UNITMS = 0 or blank; m/s if UNITMS = 1.

41-50	FCGAAMX	F10.4	Maximum value of projectile axial acceleration axis scale in g's.
51-60	FCGAAMN	F10.4	Minimum value of projectile axial acceleration axis scale in g's.

Card E Normal displacement, velocity, and acceleration scale card

List FCGNDMX, FCGNDMN, FCGNVMX, FCGNVMN, FCGNAMX, FCGNAMN

Format (6F10.4)

Columns	Symbol	Format	Description
1-10	FCGNDMX	F10.4	Maximum value of projectile normal displacement axis scale; in inches if UNITMS = 0 or blank; mm if UNITMS = 1.
11-20	FCGNDMN	F10.4	Minimum value of projectile normal displacement axis scale; in inches if UNITMS = 0 or blank; mm if UNITMS = 1.
21-30	FCGNVMX	F10.4	Maximum value of projectile normal velocity axis scale; in ft/s if UNITMS = 0 or blank; m/s if UNITMS = 1.
31-40	FCGNVMN	F10.4	Minimum value of projectile normal velocity axis scale; in ft/s if UNITMS = 0 or blank; m/s if UNITMS = 1.
41-50	FCGNAMX	F10.4	Maximum value of projectile normal acceleration in g's.
51-60	FCGNAMN	F10.4	Minimum value of projectile normal acceleration in g's.

Card F Force and point F acceleration

List FLFMX, FLFMN, FAPFMX, FAPFMN, FAFMX, FAFMN

Format (6F10.4)

Columns	Symbol	Format	Description
1-10	FLFMX	F10.4	Maximum value of lateral force axis scale; in klb if UNITMS = 0 or blank; kN if UNITMS = 1.

11-20	FLFMN	F10.4	Minimum value of lateral force axis scale; in klb if UNITMS = 0 or blank; kN if UNITMS = 1.
21-30	FAPFMX	F10.4	Maximum value of axial point F normal acceleration axis scale in g's.
31-40	FAPFMN	F10.4	Minimum value of axial point F normal acceleration axis scale in g's.
41-50	FAFMX	F10.4	Maximum value of air resistance (aerodynamic drag force) axis scale; in klb if UNITMS = 0 or blank; kN if UNITMS = 1.
51-60	FAFMN	F10.4	Minimum value of air resistance axis scale; in klb if UNITMS = 0 or blank; kN if UNITMS = 1.

Card G Yaw angle, velocity, and acceleration

List FYAWDMX, FYAWDMN, FYAWVMX, FYAWVMN, FYAWAMX, FYAWAMN

Format (6F10.4)

Columns	Symbol	Format	Description
1-10	FYAWDMX	F10.4	Maximum value of yaw angle axis scale in milliradians.
11-20	FYAWDMN	F10.4	Minimum value of yaw angle axis scale in milliradians.
21-30	FYAWVMX	F10.4	Maximum value of yaw velocity axis scale in rad/s.
31-40	FYAWVMN	F10.4	Minimum value of yaw velocity axis scale in rad/s
41-50	FYAWAMX	F10.4	Maximum value of yaw acceleration axis scale in rad/s^2.
51-60	FYAWAMN	F10.4	Minimum value of yaw acceleration axis scale in rad/s^2.

Card H Figure subtitle control card

List NT(I) I = 1,6

Format (6I10)

Columns	Symbol	Format	Description
1-10	NT(1)	I10	Control of subtitle 1; if = 1, following subtitle 1 card (card I) will be read; 0 or blank, subtitle 1 card is omitted and title of analysis (TITLEM) will be used as subtitle 1 in output figures.
11-20	NT(2)	I10	Control of subtitle 2; if = 1, following subtitle 2 card (card J) will be read; 0 or blank, subtitle 2 card is omitted and subtitle of analysis (TITLES) will be used as subtitle 2 in output figures.
21-30	NT(3)	I10	Control of subtitle 3; if = 1, following subtitle 3 card (card K) will be read; 0 or blank, subtitle 3 card is omitted and program will print c.g. eccentricity data as subtitle 3.
31-40	NT(4)	I10	Control of subtitle 4; if = 1, following subtitle 4 card (card L) will be read; 0 or blank, subtitle 4 card is omitted and program will print bore and bourrelet diameter data as subtitle 4.
41-50	NT(5)	I10	Control of subtitle 5; if = 1, following subtitle 5 card (card M) will be read; 0 or blank, subtitle 5 card is omitted and program will print friction coefficient data as subtitle 5.
51-60	NT(6)	I10	Control of subtitle 6; if = 1, following subtitle 6 card (card N) will be read; 0 or blank, subtitle 6 card is omitted and program will print spring constant data as subtitle 6.

Card I Subtitle 1 card

If NT(1) = 0 or blank, this card is omitted.

List TITLE(J,1) J=1,5

Format (5A10)

Columns	Symbol	Format	Description
1-50	TITLE(J,1)	5A10	Subtitle 1 to be printed in output figures.

Card J Subtitle 2 card

If NT(2) = 0 or blank, this card is omitted.

List TITLE(J,2) J=1,5

Format (5A10)

Columns	Symbol	Format	Description
1-50	TITLE(J,2)	5A10	Subtitle 2 to be printed in output figures.

Card K Subtitle 3 card

If NT(3) = 0 or blank, this card is omitted.

List TITLE(J,3) J=1,5

Format (5A10)

Columns	Symbol	Format	Description
1-50	TITLE(J,3)	5A10	Subtitle 3 to be printed in output figures.

Card L Subtitle 4 card

If NT(4) = 0 or blank, omit this card.

List TITLE(J,4) J=1,5

Format (5A10)

Columns	Symbol	Format	Description
1-50	TITLE(J,4)	5A10	Subtitle 4 to be printed in output figures.

Card M Subtitle 5 card

If NT(5) = 0 or blank, omit this card.

List TITLE(J,5) J=1,5

Format (5A10)

Columns	Symbol	Format	Description
1-50	TITLE(J,5)	5A10	Subtitle 5 to be printed in output figures.

Card N Subtitle 6 card

If NT(6) = 0 or blank, omit this card.

List TITLE(J,6) J=1,5

Format (5A10)

Columns	Symbol	Format	Description
1-50	TITLE(J,6)	5A10	Subtitle 6 to be printed in output figures.

9. Firing pressure card set (2-26 cards)

Card A General information card

List NOFP, NCHAMP, CWT, PCGX, UNITFP

Format (2I10, 4F10.5)

Columns	Symbol	Format	Description
1-10	NOFP	I10	Number of pressure-time data pairs.
11-20	NCHAMP	I10	Type of firing pressure; enter 1 for chamber pressure; 0 or blank for base pressure.
21-30	CWT	F10.5	Weight of propellant charge; in lb if UNITFP = 0 or blank; kg if UNITFP = 1.
31-40	PCGX	F10.5	Base pressure center to c.g. distance; in inches if UNITFP = 0 or blank; cm if UNITFP = 1.0; default value = CGX.
41-50	UNITFP	F10.5	Unit of pressure input; if = 0 or blank, pressure in psi; if = 1.0, pressure in kPa.

Card B Time-pressure cards

List FPT(I), FP(I), I=1, NOFP

Format (4(F10.5, F10.2))

Columns	Symbol	Format	Description
1-10	FPT(I)	F10.5	Time in ms
11-20	FP(I)	F10.2	Pressure at time FPT(I); in psi if UNITFP = 0 or blank; kPa if UNITFP = 1.0.

Enter successive time-pressure data pairs in successive columns: 21-30, 31-40, 41-50, 51-60, 61-70, and 71-80. Repeat card B procedure until all data are entered.

10. Worn tube card set (1-26 cards)

Card A General information card

List NOTW, UNITTW

Format (I10, F10.5)

Columns	Symbol	Format	Description
1-10	NOTW	I10	Number of tube wear data pairs.
11-20	UNITTW	F10.5	Unit of tube wear data; if = 0 or blank, data in English units; if = 1.0, data in metric units.

If NOTW = 0, following card B is omitted.

Card B Distance-wear cards

List TWMX(I), TWDC(I), I=1, NOTW

Format (8F10.5)

Columns	Symbol	Format	Description
1-10	TWMX(I)	F10.5	Distance from muzzle to tube wear location, in inches if UNITTW = 0 or blank; cm if UNITTW = 1.0.
11-20	TWDC(I)	F10.5	Change of bore diameter; in mils of inch if UNITTW = 0 or blank; mm if UNITTW = 1.0.

Enter successive data pairs in successive columns: 21-30, 31-40, 41-50, 51-60, 61-70, and 71-80. Repeat card B procedure until all data are entered.

11. Bourrelet elasticity card set (1-26 cards)

Card A General information card

List NOEBK, BRTK, BRTE, UNITBK

Format (I10, 3F10.4)

Columns	Symbol	Format	Description
1-10	NOEBK	I10	Number of experimental bourrelet deflection-load data pairs.
11-20	BRTK	F10.4	Average or linear bourrelet spring constant, used when experimental deflection-load data are not available; in 10^6 lb/in if UNITBK = 0 or blank; 10^6 N/cm if UNITBK = 1.0.
21-30	BRTE	F10.4	Young's modulus of bourrelet material, used to compute approximate spring constant when test data and average spring constant are not available; in 10^6 psi if UNITBK = 0 or blank; 10^6 kPa, if UNITBK = 1.0.
31-40	UNITBK	F10.4	Unit of bourrelet elasticity data; if = 0 or blank, data in English units; if = 1.0, data in metric units.

If NOEBK = 0, omit following card B.

Card B Deflection-load cards

List BDEF(I), BLOAD(I), I=1, NOEBK

Format (4(F10.5, F10.2))

Columns	Symbol	Format	Description
1-10	BDEF(I)	F10.5	Diametrical deflection of bourrelet; in inches if UNITBK = 0 or blank; cm if UNITBK = 1.0.

11-20	BLOAD(I)	F10.2	Load applied at bourrelet deflection test corresponding to deflection BDEF(I); in lb if UNITBK = 0 or blank; N if UNITBK = 1.0.

Enter successive deflection-load data pairs in successive columns: 21-30, 31-40, 41-50, 51-60, 61-70, and 71-80. Repeat card B procedure until all data are entered.

12. Rotating band elasticity card set (1-51 cards)

Card A General information card

List NOERBK, NOERBMK, RBK, RBMK, RTBAND, UNITRBK

Format (2I10, 4F10.4)

Columns	Symbol	Format	Description
1-10	NOERBK	I10	Number of experimental rotating band deflection test data pairs.
11-20	NOERBMK	I10	Number of experimental transverse rotation at rotating band test data pairs.
21-30	RBK	F10.4	Average or linear spring constant of rotating band; in 10^6 lb/in if UNITRBK = 0 or blank; 10^6 N/cm if UNITRBK = 1.0.
31-40	RBMK	F10.4	Average or linear angular spring constant of rotating band; in 10^6 in-lb/deg if UNITRBK = 0 or blank; 10^6 cm-N/rad if UNITRBK = 1.0.
41-50	RTBAND	F10.4	Identification of rotating band; = 1.0 when rotating band is used; = 0 or blank, when obturator is used.
51-60	UNITRBK	F10.4	Unit of spring constant data; if = 0 or blank, English units are used; if = 1.0, metric units are used.

If NOERBK = 0, omit following card B.

Card B Deflection-load cards

List RBDEF(I), RBLOAD(I), I=1, NOERBK

Format	(4(F10.5, F10.2))		

Columns	Symbol	Format	Description
1-10	RBDEF(I)	F10.5	Diametrical deflection of rotating band in inches if UNITRBK = 0 or blank; cm if UNITRBK = 1.0.
11-20	RBLOAD(I)	F10.2	Load applied at rotating band deflection test corresponding to deflection RBDEF(I); in lb if UNITRBK = 0 or blank; N if UNITRBK = 1.0.

Enter successive deflection-load data pairs in successive columns: 21-30, 31-40, 41-50, 51-60, 61-70, and 71-80. Repeat card B procedure until all data are entered. If NOERBMK = 0 or blank, omit following card C.

Card C Angular deflection-moment cards

List RBANG(I), RBM(I), I=1, NOERBMK

Format (4(F10.5, F10.2))

Columns	Symbol	Format	Description
1-10	RBANG(I)	F10.5	Angular deflection or transverse rotation of projectile at rotating band; in deg if UNITRBK = 0 or blank; rad if UNITRBK = 1.0.
11-20	RBM(I)	F10.2	Moment applied at rotating band angular deflection test corresponding to angular deflection RBANG(I); in in-lb if UNITRBK = 0 or blank; cm-N, if UNITRBK = 1.0.

Enter successive angular deflection-moment data pairs in successive columns: 21-30, 31-40, 41-50, 51-60, 61-70, and 71-80. Repeat card C procedure until all data are entered.

13. Friction card set (1-27 cards)

Card A Friction coefficient and general information card

List NORBPR, RBPRAV, RBMU, BRTMU, RBPW, RBPRMR, RBNU, UNITRBP

Format (I10, F10.2, 6F10.5)

Columns	Symbol	Format	Description
1-10	NORBPR	I10	Number of gun tube-rotating band contact pressure data pairs.
11-20	RBPRAV	F10.2	Average gun tube-rotating band contact pressure; in psi if UNITRBP = 0 or blank; kPa if UNITRBP = 1.0; not entered when NORBPR is not zero or when pressure will be computed in the program.
21-30	RBMU	F10.5	Friction coefficient at rotating band.
31-40	BRTMU	F10.5	Friction coefficient at bourrelet.
41-50	RBPW	F10.5	Effective width of rotating band for gun tube-rotating band contact pressure computation in the program; in inches if UNITRBP = 0 or blank; cm if UNITRBP = 1.0; default value = RBW.
51-60	RBPRMR	F10.5	Known or estimated ratio of gun tube-rotating band contact pressure at muzzle to that at breech; default value = 0.5.
61-70	RBNU	F10.5	Poisson's ratio of rotating band material.
71-80	UNITRBP	F10.5	Unit of gun tube-rotating band contact pressure input data; = 0 or blank if English units are used; = 1.0 if metric units are used.

If RBPRAV is not zero, omit following cards B and C. If RBNU is zero, omit following card B.

Card B Rotating band card

List RBOD, RBID, RBE, PROJRBD

Format (4F10.5)

Columns	Symbol	Format	Description
1-10	RBOD	F10.5	Initial outer diameter of rotating band; in inches if UNITRBP = 0 or blank; cm if UNITRBP = 1.0
11-20	RBID	F10.5	Initial inner diameter of rotating band if it is different from projectile diameter at band seat, or initial inner diameter of obturator before it is fitted to projectile; in inches if UNITRBP = 0 or blank; cm if UNITRBP = 1.0; default value = band seat diameter of projectile (PROJRBD)
21-30	RBE	F10.5	Young's modulus of rotating band material; in 10^6 psi if UNITRBP = 0 or blank; 10^6 kPa if UNITRBP = 1.0.
31-40	PROJRBD	F10.5	Diameter of band seat of projectile; in inches if UNITRBP = 0 or blank; cm if UNITRBP = 1.0.

If NORBPR is zero, omit folliwng card C.

Card C Distance-pressure card

List RBPMX(I), RBPR(I), I=1, NORBPR

Format (4(F10.5, F10.2))

Columns	Symbol	Format	Description
1-10	RBPMX(I)	F10.5	Distance of gun tube-rotating band pressure location from muzzle; in inches if UNITRBP = 0 or blank; cm if UNITRBP = 1.0.
11-20	RBPR(I)	F10.2	Gun tube-rotating band pressure; in psi if UNITRBP = 0 or blank; kPa if UNITRBP = 1.0.

Enter successive distance-pressure data pairs in successive columns: 21-30, 31-40, 41-50, 51-60, 61-70, and 71-80. Repeat card C procedure until all data are entered.

14. Air resistance card set (1-77 cards)

Card A General information and drag card

List NOCD, CDAV, RHO, AC, DTALAM, UNITAF

Format (I10, 5F10.5)

Columns	Symbol	Format	Description
1-10	NOCD	I10	Number of yaw angle-aerodynamic drag coefficient data pairs.
11-20	CDAV	F10.5	Average or constant drag coefficient.
21-30	RHO	F10.5	Air mass density; in lbm/in^3 if UNITAF = 0 or blank; kg/cm^3 if UNITAF = 1.0; default value = standard density at sea level (0.002378 $slug/ft^3$) is used in the program.
31-40	AC	F10.5	Location of aerodynamic center or axial distance from projectile c.g. section to axial point where aerodynamic pressure center intersects; in inches if UNITAF = 0 or blank; cm if UNITAF = 1.0.
41-50	DTALAM	F10.5	Control number of aerodynamic lift and moment; if = 0 or blank, no data of lift and moment are used in the computation or lift and moment are ignored; if = 1.0, data are entered in following cards C and D.
51-60	UNITAF	F10.5	Unit of aerodynamic yaw-coefficient data; data in English units if UNITAF = 0 or blank; in metric units if UNITAF = 1.0.

If NOCD = 0, omit following card B.

Card B Drag coefficient card

List CDANG(I), CD(I), I=1, NOCD

Format (8F10.5)

Columns	Symbol	Format	Description
1-10	CDANG(I)	F10.5	Yaw angle or angle of attack; in deg if UNITAF = 0 or blank; rad if UNITAF = 1.0.

11-20	CD(I)	F10.5	Aerodynamic drag coefficient corresponding to yaw angle CDANG(I).

Enter successive angle-coefficient data pairs in successive columns: 21-30, 31-40, 41-50, 51-60, 61-70, and 71-80. Repeat card B procedure until all data are entered. If DTALAM = 0 or blank, omit following cards C-E.

Card C Lift and moment information card

List NOCL, NOCM, CLAV, CMAV, CHORD

Format (2I10, 3F10.5)

Columns	Symbol	Format	Description
1-10	NOCL	I10	Number of aerodynamic lift coefficient data pairs.
11-20	NOCM	I10	Number of aerodynamic moment coefficient data pairs.
21-30	CLAV	F10.5	Average or constant aerodynamic lift coefficient; entered when NOCL = 0.
31-40	CMAV	F10.5	Average or constant aerodynamic moment coefficient; entered when NOCM = 0.
41-50	CHORD	F10.5	Length of equivalent airfoil chord for aerodynamic moment computation; in inches if UNITAF = 0 or blank; cm if UNITAF = 1.0; default value = PROJL (length of projectile).

If NOCL = 0, omit following card D.

Card D Lift coefficient card

List CLANG(I), CL(I), I=1, NOCL

Format (8F10.5)

Columns	Symbol	Format	Description
1-10	CLANG(I)	F10.5	Yaw angle or angle of attack; in deg if UNITAF = 0 or blank; rad if UNITAF = 1.0.

11-20	CL(I)	F10.5	Aerodynamic lift coefficient corresponding to CLANG(I).

Enter successive angle-coefficient data pairs in successive columns: 21-30, 31-40, 41-50, 51-60, 61-70, and 71-80. Repeat card D procedure until all data are entered.

Card E Moment coefficient card

If NOCM = 0, omit this card.

List CMANG(I), CM(I), I=1, NOCM

Format (8F10.5)

Columns	Symbol	Format	Description
1-10	CMANG(I)	F10.5	Yaw angle or angle of attack; in deg if UNITAF = 0 or blank; rad if UNITAF = 1.0.
11-20	CM(I)	F10.5	Aerodynamic moment coefficient corresponding to CMANG(I).

Enter successive angle-coefficient data pairs in successive columns: 21-30, 31-40, 41-50, 51-60, 61-70, and 71-80. Repeat card E procedure until all data are entered.

15. End card (1 card)

An end-of-record (EOR) job control (7-8-9) card which consists of a 7-8-9 multipunch in column 1 is used as the end card of the input data deck.

To facilitate the preparation of the input data cards and for easy reference, the above-mentioned cards are summarized in appendix A.

OPERATION

The program is operated with job control and data cards. It has been operated on a CDC 6000 series computer with an in-line Nicolet Zeta digital drum plotter or similar one for curve plotting. It may be adapted to be operated at a Tektronix 4014 or similar graphics terminal to get an "instant" copy of a figure. The program requires approximately 120000_8 words of core. Detailed information of job deck setup for the computer run may be obtained from the operator of the user's computer terminal and is not discussed here.

It should be noted that the accuracy of computation will depend on the input values of different data, especially the spring constants and other force and moment coefficients. Experimental data are preferred whenever they are availa-

ble. Furthermore, the time step size affects the processing and the accuracy of numerical solution. Therefore, it is important to use very small time step sizes (microseconds or less) to obtain good results. The F conversion formats used in the program are suitable for general projectile computations. To accommodate for larger or smaller values they should be changed to E conversion formats if necessary.

EXAMPLE OF COMPUTATION

An example of using the program is presented here. The problem is to analyze a 7 kg projectile launched in a 120-mm smooth gun tube. Most of the input data, such as the dimensions and physical properties of the projectile and gun tube, are obtained from design drawings, design error budget, or data of similar projectiles. Other data are determined from experimental results, approximate computations, or engineering handbooks.

The projectile c.g. eccentricity has a magnitude of 0.254 mm and the projectile is initially positioned so that the c.g. is at the six o'clock position and the bourrelet contacts the gun tube. Thus, the c.g. is under the projectile geometrical axis. It is, therefore, taken as -0.254 mm for the input value. The six o'clock position indicates that the X-Y plane is vertical and, therefore, β is zero. The gun tube is held in a horizontal position, therefore, α is also zero.

The spring constant of the bourrelet is obtained from the compression tests of the projectile, and the average value of the results is used. The bourrelet load-deflection curve data may be used instead of the average value if more accurate results are desired. The angular spring constant of the obturator is taken as zero since the yaw angle is small and no test data are available. The frictional coefficients and the in-bore aerodynamic coefficients are also not available at present. The lift and moment coefficients of air resistance are taken as zero since they are small. The drag coefficient is assumed to be unity in order to get some idea of the magnitude of the in-bore air resistance. The frictional coefficients at the bourrelet and the obturator are assumed to be 0.15 and 0.04 based on the similar data of steel to steel and teflon to steel (ref 8).

The base firing pressure-time data are determined from an interior ballistics computation as shown in figure 23 and in table 3 of appendix B.

The detailed input dimensions and physical properties of the projectile and the gun tube are indicated in table 1 of appendix B.

The title of this computation is "Example of Computation of Program BALLOT2." The subtitle is blank. English units are used in the input data preparation. Therefore, NDAMS and NDARAD are both zero. Other unit control numbers except NPOPDTA (=20) are also zero. Consequently, the default values in the program are used. Then the input data tables are printed out; the intermediate computation check values are printed out every 15th value recorded on the magnetic tape; the output table of maximum, minimum, and muzzle values is printed; and

every 20th value of the computed values recorded on the magnetic tape is printed out.

The maximum time of computation is 4.8 ms and the step size is 0.001 ms. The constant step size computation is required so TSLAST is zero.

All output figures plotted against both time and travel are desired, consequently, all figure plot controls are 1. The maximum and minimum scales of output figures are to be determined by the program and, therefore, are all zero.

The title of this computation will be used as one of the subtitles of the output figures and no special subtitles are desired. Therefore, all NT(I) are zero and no subtitle cards are needed.

Other input data are determined according to instructions stated in the input data coding. The input data card arrangement is easily understood by comparing it (table 1 of appendix B) with the input data tables (tables 2 through 5 of appendix B).

With the input data determined, the input data cards are punched according to the coding formats mentioned before. These data cards, together with the program and job control cards, form the job card deck which is placed in the card reader of a CDC 6000 series computer terminal to be read and executed by the computer. The printed output and plotted figures are shown in appendix B.

Table 1. List of labeled common blocks

Common block	Used in: BALLOT2	DIPTBL	DATAINP	FIGCTRL	FGOV3	FGDA3	FGMN3	FGPRTSB	OPTBL
CMXMN	X			X					X
CMXMNA	X								X
CMXMNT	X								X
CMXMNX	X								X
DIM	X		X						
DTDI		X	X						
DTDIMA	X	X	X						
DTDIMB	X	X	X						
DTDIMC	X	X	X						
DTDIMD	X	X	X						
DTDIOM	X	X	X						X
DTDIOMF	X	X	X	X					X
DTM	X	X							
FGCVA				X	X				
FGCVB				X		X			
FGCVC					X	X	X	X	
FGCVE					X		X		
FGCVF				X	X	X	X		
FGDIA			X	X					
FGDIB			X	X					
FGDIVM	X		X	X					
OPTBMA	X								X
OPTBMB	X								X

Table 2. Definitions of symbols used in main program

Symbol	Description
A	Area of gun tube bore - in^2
AC	Axial distance of projectile c.g. to aerodynamic center, used for air resistance computation - in
ADD; FDD	Normal acceleration at projectile axial point A, F - in/s^2
ADDM, ADDN; FDDM, FDDN	Maximum, minimum value of ADD;FDD
ADDMT, ADDNT; FDDMT, FDDNT	Time when ADD;FDD is maximum, minimum - ms
ADDMX, ADDNX; FDDMX, FDDNX	Travel of projectile when ADD;FDD is maximum, minimum - in
ALPHA	Gun tube elevation angle - rad
AM	Total aerodynamic moment about projectile c.g. - in-lb
APFXM	Distance of projectile axial point F from projectile nose in metric unit - cm
AR	Ratio of specific heats of propellant gases
BDEF	Deflection of bourrelet compression test - in
BETA	Angle between vertical and x-y plane - rad
BK	Average spring constant of bourrelet - lb/in
BLOAD	Load applied at bourrelet compression test - lb
BM	Total moment of all forces at bourrelet - in-lb
BMU, BRTMU	Friction coefficient at bourrelet
BN	Normal force at bourrelet - lb
BNM, BNN	Maximum, minimum of BN
BNMT, BNNT; BNMX, BNNX	Time; travel of projectile when BN is maximum, minimum - ms
BNRM	BN expressed in newtons

Table 2. (cont)

Symbol	Description
BORED	Gun tube bore diameter - in
BOREDM	Bore diameter expressed in cm
BP	Base pressure used in computation - psi
BPSLP	Slope of base pressure-time curve
BRTE	Young's modulus of bourrelet - 10^6 psi
BRTK	Average spring constant of bourrelet - 10^6 lb/in
BRTKM	BRTK expressed in metric unit - 10^6 N/cm
BRTOD	Bourrelet outside diameter - in
BRTODM	BRTOD expressed in metric unit - cm
BRTTK	Thickness of projectile wall at bourrelet - in
BRTW	Length of bourrelet portion having diameter = BRTOD - in
BRTX	Distance of bourrlet from projectile base plane - in
CD, CL, CM	Aerodynamic coefficient of drag, lift, moment for projectile in-bore motion
CDANG, CLANG, CMANG	Yaw angle for computing in-bore aerodynamic coefficient CD, CL, CM - rad
CDAV, CLAV, CMAV	Average CD, CL, CM
CGEL	c.g. eccentricity expressed in distance - in
CGELM	CGEL expressed in metric unit - cm
CGEMT	Projectile c.g. eccentricity expressed in unbalanced moment - in-oz
CGEMTM	CGEMT expressed in metric unit - cm-kg
CGX	Distance of projectile c.g. to base plane - in
CGXM	CGX expressed in metric unit - cm
CHORD	Reference length for in-bore aerodynamic moment computation - in

Table 2. (cont)

Symbol	Description
CTHETA	Cosine of angle theta
CW	Ratio fo charge weight to projectile weight
CWT	Charge weight - lb

Table 2. (cont)

Symbol	Description
DABSGN	Sign of bourrelet deflection
DAOSGN	Sign of rotating band deflection
DELTAB, DELTAO	Maximum normal deflection at bourrelet, rotating band - in
DELTAT	Time step size - sec
FB	Frictional force at bourrelet - lb
FD, FL	Aerodynamic drag, lift force - lb
FLM, FLN	Maximum, minimum FL - lb
FLMT, FLNT	Time when FL is maximum, minimum - ms
FLMX, FLNX	Travel of projectile when FL is maximim, minimum - in
FO1	Frictional force at rotating band due to uniform gun tube-rotating band contact pressure - lb
FO1CF	Product of tube-band contact area and friction coefficient
FO2	Friction force due to normal force at rotating band - lb
FP	Base pressure - psi
FPEA	Effective base pressure acting area - in^2
FPT	Time value of firing pressure-time data - ms
FX, FY	Total force acting at projectile c.g. in X, Y direction - lb
GX, GY	X, Y component of gravitational force at projectile c.g. - lb
H	Distance of bourrelet to c.g. section - in

Table 2. (cont)

Symbol	Description
HH	Projectile c.g. distance to muzzle - in
HXL	Distance between bourrelet and rotating band mid-section - in
HXLM	HXL expressed in metric unit - cm
NBK, NBRTKC	Control number in bourrelet spring constant computation
NC	Total number of computations
NCCK	Control number in printing out some computed results during computation
NCD, NCL, NCM	Control number in aerodynamic coefficient computation for drag, lift, moment
NCHAMP	Control number in conversion of chamber to base pressure
NFP, NOK, NOMK, NOP	Control number in base pressure, gun tube-rotating band contact pressure, angular spring constant, given tube-band contact pressure computation
NIDTBL, NOOPDTA, NOPTBL, NPOPDTA	Control number in printing out input data table, recording output data, printing out output data table, detailed output data
NOCD, NOCL, NOCM NOEBK, NOERBK, NOERBMK, NOFP, NORBPR, NOTW	Number of input data pairs for input data of aerodynamic drag, lift, moment, bourrelet spring constant, rotating band spring constant, angular spring constant, firing pressure, gun tube-rotating band contact pressure, gun tube wear
NOCP	Estimated total number of computations
NR	Number of computed results recorded on tape 1
NRD, NWD	Control number in recording computed data
NT	Control number in reading figure subtitle
NTBL	Number of tables printed
NWRB, NWRO	Control number in computing tube wear at bourrelet, rotating band

Table 2. (cont)

Symbol	Description
OK, OMK	Spring constant - lb/in, angular spring constant of rotating band - in-lb/rad
OMU, RBMU	Friction coefficient of rotating band
OM1, OM2, OM3	Moment about projectile c.g. from rotating band friction force (FO1), normal force (ON), and friction force (FO2) transverse rotation resisting moment - in-lb
ON	Normal force at rotating band, N_o - lb
ONM, ONN	Maximum, minimum N_o - lb
ONMT, ONNT	Time when N_o is maximum, minimum - ms
ONMX, ONNX	Projectile travel when N_o is maximim, minimum - in
ONRM	N_o expressed in metric unit - N
OPSLP	Slope of gun tube-rotating band contact pressure data curve
P	Total base pressure - lb
PAD, PFD	Distance of axial point A, F to c.g. - in
PCGX	Distance of base pressure center to c.g. - in
PM, PN	Maximum, minimum P - lb
PMT, PNT	Time when P is maximum, minimum - ms
PMX, PNX	Projectile travel when P is maximim, minimum - in
PRM	Moment of total base pressure about c.g. - in-lb
PROJRBD	Diameter of rotating band seat - in
PWT	Weight of projectile - lb
PX, PY	X, Y component of P - lb
R, RO	Radius of gun tube bore - in
RB	Radius of bourrelet - in

Table 2. (cont)

Symbol	Description
RBANG, RBM	Turning angle, deg; moment, in-lb of rotating band transverse resisting moment data
RBD	Outer radius of rotating band when projectile is loaded in gun tube - in
RBDEF, RBLOAD	Deflection, in; applied load, lb of rotating band compression test data
RBE	Young's modulus of rotating band - 10^6 psi
RBID, RBOD	Inner, outer diameter of rotating bnad before it is fitted on projectile band seat - in
RBK, RBMK	Spring constant - 10^6 lb/in; angular spring constant of rotating band - 10^6 in-lb/deg
RBKM	RBK expressed in metric unit - 10^6 N/cm
RBNU	Poisson's ratio of rotating band material
RBPMX, RBPR	Distance, in; pressure, psi of gun tube-rotating band pressure input data
RBPRAV	Average gun tube-rotating band contact pressure - psi
RBPRC	Gun tube-rotating band contact pressure at breech end, computed in the program - psi
RBPRCM	RBPRC expressed in metric units - kPa
RBPRMR	Ratio of gun tube-rotating band contact pressure at muzzle and to that at breech
RBPW	Effective width of rotating band used to compute total gun tube-rotating band contact pressure - in
RBW	Nominal width of rotating band - in
RBX	Distance from projectile base to nearest side of rotating band - in
RHO	Air density used to compute aerodynamic forces (0.002378 slugs/ft^3 for default value)
RTBAND	Control number to identify rotating band or obturator

Table 2. (cont)

Symbol	Description
STHETA	Sine of angle alpha
TADDMX, TADDNX	Projectile travel when yaw acceleration is maximum, minimum - in
TADMX, TADNX	Projectile travel when yaw velocity is maximum, minimum - in
TAMX, TANX	Projectile travel when yaw angle is maximum, minimum - in
TBRB, TBRO	Radius of worn gun tube bore at location of bourrelet, rotating band - in
THETA	Yaw angle - rad
THETAC	Yaw angle when bourrelet just contacts gun tube at 6 o'clock position - rad
THETACO	THETAC expressed in degree
THETAD	Yaw velocity - rad/s
THETAM, THETAN	Maximum, minimum yaw angle - rad
THETAMT, THETANT	Time when yaw angle is maximum, minimum - ms
THETAO	THETA expressed in degree
THETAPM	THETA expressed in milliradians
THETAR	Control number in using computed contact yaw angle as initial position
THTADD	Yaw acceleration - rad/s^2
THTADM, THTADN	Maximum, minimum yaw velocity - rad/s
THTADMT, THTADNT	Time when yaw velocity is maximum, minimum - ms
THTASGN	Sign of THETA or yaw angle
TI	Time step size used in computation - sec
TIAV	Average time step size - sec
TII	Increment of time step size used in variable time step size computation - sec

Table 2. (cont)

Symbol	Description
TIME	Time in computation - ms
TITLE	Subtitle of output figure
TITLEM	Title of analysis or computer run, also used as figure subtitle if no subtitle is given
TITLES	Subtitle of analysis or computer run, also used as figure subtitle if no subtitle is given
TMAX	Estimated or desired time of computation, also used as max value of time scale in plotting figures - ms
TMOI	Transverse moment of inertia of projectile - $lb\text{-}in^2$
TRAVEL	Travel or maximum displacement of projectile - in
TRAVELM	TRAVEL expressed in metric unit - m
TSLAST	Last time step size of uniformly decreased step size computation - ms
TSTEP	Time step size for constant step size computation or first step size for uniformly decreased step size computation - ms
TTADDM, TTADDN	Maximum, minimum yaw acceleration - rad/s^2
TTADDMT, TTADDNT	Time when yaw acceleration is maximum, minimum - ms
TTHETA	Tangent of angle theta
TWDC, TWMX	Change in gun tube bore diameter, mil; distance, in of worn tube input data
VB	Velocity of bourrelet contact point where normal force resultant acts - in/s
VBSGN	Sign of velocity VB
VO	Velocity of rotating band contact point where normal force resultant acts - in/s
VOSGN	Sign of velocity VO
WRB, WRO	Change in radius of worn gun tube at location of bourrelet, rotating band - in

Table 2. (cont)

Symbol	Description
WROSLP	Slope of worn gun tube data curve
X, XB	Travel or axial displacement of projectile c.g., bourrelet - in
XBMZL	Bourrelet distance to muzzle - in
XD, XDD	Axial projectile velocity - in/s; acceleration - in/s^2
XDDM, XDDN	Maximum, minimum XDD - in/s^2
XDDMT, XDDNT	Time when XDD is maximum, minimum - ms
XDDMX, XDDNX	Projectile travel when XDD is maximum, minimum - in
XDDR	XDD expressed in g's
XDR	XD expressed in ft/s
XDRM	XC expressed in m/s
XI, YI	X, Y value of initial c.g. location - in
XIM, YIM	XI, YI expressed in metric unit - cm
XL	Distance of c.g. to mid-section of rotating band - in
XMASS	Mass of projectile - slug/12
XRM	Projectile axial displacement or travel expressed in metric unit - cm
XTMOI	TMOI expressed in slug-in^2/12
Y	Normal displacement of projectile c.g. - in
YD, YDD	Normal velocity - in/s, acceleration of projectile c.g. - in/s^2
YDDM, YDDN	Maximum, minimum YDD - in/s^2
YDDMT, YDDNT	Time when YDD is maximum, minimum - ms
YDDMX, YDDNX	Projectile travel when YDD is maximum, minimum - in
YDDR	YDD expressed in g's

Table 2. (cont)

Symbol	Description
YDM, YDN	Maximum, minimum YD - in/s
YDMT, YDNT	Time when YD is maximum, minimum - ms
YDMX, YDNX	Projectile travel when YD is maximum, minimum - in
YDR	YD expressed in ft/s
YDRM	YD expressed in m/s
YM, YN	Maximum, minimum Y - in
YMT, YNT	Time when Y is maximum, minimum - ms
YMX, YNX	Projectile travel when Y is maximum, minimum - in
YRM	Y expressed in metric unit - cm
ZM	Total moment about Z axis - in-lb

Table 3. Definitions of symbols used in subroutine CLIPV

Symbol	Description
XD, YD	Variable or data pairs
XD(N), YD(N)	Nth variables or data pairs
XO	Known intermediate value of XD
X	Absolute value of XO
YO	Intermediate value of YD to be computed
SLP	Slope of XD-YD curve in computation
ND	Number of data pairs

Table 4. Definitions of symbols used in subroutine CMAXMIN

Symbol	Description
X	Variable, its maximum and minimum values are to be determined
XM	Maximum value of X
XN	Minimum value of X
TM, TN	Time when maximum, minimum value of X is first computed
DM, DN	Axial projectile displacement when maximum, minimum value of X is first computed
T	Time corresponding to X
D	Axial projectile displacement corresponding to X

Table 5. Definitions of symbols used in subroutine DATAINP

Symbol	Description
ACM	Axial distance of projectile c.g. to aerodynamic center, expressed in metric unit - cm
ALPHAO	Alpha expressed in degrees
APAX, APFX	Distance of projectile axial point A, F to projectile nose - in
APAXM	APAX expressed in metric unit - cm
BETAO	BETA expressed in degrees
BRTEM	BRTE expressed in metric unit - 10^6 kPa
BRTID	Inside diameter at bourrelet - in
BRTIDM	BRTID expressed in metric unit - cm
BRTTKM	BRTTK expressed in metric unit - cm
BRTWM	BRTW expressed in metric unit - cm
BRTXM	BRTX expressed in metric unit - cm
CGD	Projectile diameter at c.g. - in
CGDM	CGD expressed in metric unit - cm
CHORDM	CHORD expressed in metric unit - cm
CWTM	CWT expressed in metric unit - kg
FAFMN, FAFMX	Minimum, maximum figure scale of aerodynamic drag force - kN
FAPFMN, FAPFMX	Minimum, maximum figure scale of normal acceleration at axial point F - g's
FCGAAMN, FCGAAMX	Minimum, maximum figure scale of axial projectile acceleration - g's
FCGADMN, FCGADMX	Minimum, maximum figure scale of axial projectile displacement - m
FCGAVMN, FCGAVMX	Minimum, maximum figure scale of axial projectile velocity, m/s

Table 5. (cont)

Symbol	Description
FCGNAMN, FCGNAMX	Minimum, maximum figue scale of normal projectile acceleration, g's
FCGNDMN, FCGNDMX	Minimum, maximum figure scale of normal projectile displacement - mm
FCGNVMN, FCGNVMX	Minimum, maximum figure scale of normal projectile velocity - m/s
FGTMAX, FGXMAX	Maximum time, ms; travel (or axial displacement) scale of output figure - in
FGXMAXM	FGXMAX expressed in metric unit - m
FLFMN, FLFMX	Minimum, maximum figure scale of lateral or normal force - kN
FPEAM	FPEA expressed in metric unit - cm^2
FTMAX, FTMIN	Maximum, minimum figure scale of time - ms
FXMAX, FXMIN	Maximum, minimum figure scale of travel or axial displacement - in
FYAWAMN, FYAWAMX	Minimum, maximum figure scale of yaw acceleration - rad/s^2
FYAWDMN, FYAWDMX	Minimum, maximum figure scale of yaw angle - milliradians
FYAWVMN, FYAWVMX	Minimum, maximum figure scale of yaw velocity - rad/s
MXMN	Control number of figure scale input data
NAF, NAPFA, NCGDVAA, NCGDVAN, NLF, NYAWA, NYAWDV	Control number of figure plotting of air resistance force, normal acceleration at axial point F, axial projectile motion, normal projectile motion, lateral forces, yaw acceleration, yaw angle, and velocity
NFGVSX	Control number for plotting curves against travel
NPLOT	General control number of figure plotting
PCGXM	PCGX expressed in metric unit - cm
PROJL	Length of projectile - in
PROJLM	PROJL expressed in metric unit - cm

Table 5. (cont)

Symbol	Description
PWTM	PWT expressed in metric unit - kg
RBDM	RBD expressed in metric unit - cm
RBEM	RBE expressed in metric unit - 10^6 kPa
RBIDM	RBID expressed in metric unit - cm
RBMKM	RBMK expressed in metric unit - cm-N/rad
RBODM	RBOD expressed in metric unit - cm
RBPRAVM	RBPRAV expressed in metric unit - kPa
RBPWM, RBWM, RBXM	RBPW, RBW, RBX epxressed in metric unit - cm
RHOM	RHO expressed in metric unit - g/cm^3
UNITAF, UNITBK, UNITFP UNITMS, UNITRBK, UNITRBP, UNITTW	Control number of input data units for input data of aerodynamic forces, bourrelet elasticity, firing pressure, dimensions and physical properties, band elasticity, gun tube-band contact pressure, gun tube wear

Table 6. Definitions of symbols used in subroutine DTARO

Symbol	Description
X,Y	Data pairs
NODATA	Number of data pairs
XO	New reference point or origin location (distance from first data pair to new origin)
YRTO	Ratio of converted Y value to original Y value

Table 7. Definitions of symbols used in subroutine DTATBL

Symbol	Description
X(I), Y(I)	Given data pairs, X,Y
XA, YA; XB, YB	Converted data pairs to be printed in one line
M, NFORMAT	Format statement reference number
NODATA	Number of data pairs
XRTO, YRTO	Conversion ratio of X,Y

Table 8. Definitions of symbols used in subroutine FIGCTRL

Symbol	Description
APFSTL	Figure subtitle indicating location of axial point F
ENDLBL	End label of output curve
FDDMM, FDDNM	FDDM, FDDN expressed in g's
FDMM, FDNM	Maximum, minimum aerodynamic drag force expressed in kN
FNMM, FNNM	Maximum, minimum lateral force expressed in kN
FTS	Space between first figure subtitle line and top of figure - in
GEE	Acceleration unit conversion factor
HBEDGE	Distance of bottom edge of graph paper to X axis of figure - in
HEL, HFT, HL, HTL	Height of character of curve end label, figure title, axial point F distance subtitle, figure subtitle - in
MXN	Control number = MXMN
NFG	Graph location control number
NODA, NODTA	Number of curve data
PFDM	PFD expressed in metric unit - cm
TD2, TD3, TD4, TD5, TD6, TD7, TD8, TD9, TD10, TD11, TD15, TD16, TD18, TD31	Tape recorded data for time, travel, normal projectile displacement, yaw angle, axial projectile velocity, normal projectile velocity, yaw velocity, axial projectile acceleration, normal projectile acceleration, yaw acceleration, lateral force at rotating band, lateral force at bourrelet, aerodynamic drag force, normal acceleration at axial point F
THETAMM, THETANM	THETAM, THETAN expressed in milliradians
TLABEL	Time axis label
TS	Space between figure subtitle lines - in
WHR	Ratio of label character width to height
XDDMM, XDDNM	XDDM, XDDN expressed in g's

Table 8. (cont)

Symbol	Description
XDMM, XDNM	XDM, XDN expressed in metric unit - m/s
XLABEL, YLABEL	Label of figure axis X,Y
XMM, XNM	Maximum, minimum X expressed in metric unit - m
XSIZE, YSIZE	Length of figure axis X,Y - in
XSPACE, YSPACE	Distance between figurs in X,Y direction - in
YDDMM, YDDNM	YDDM, YDDN expressed in g's
YDMM, YDNM	YDM, YDN expressed in metric unit - m/s
YMM, YNM	YM, YN expressed in metric unit - mm

Table 9. Definitions of symbols used in subroutine FGCV3

Symbol	Description
ELX, ELY	Starting X,Y coordinates to print curve end label
FGTITLE	Title of figure
NOCRV	Number of curves plotted in one graph
NPLNO	Number of figure plotting
OX, OY	X,Y coordinates of figure origin
X	Common X coordinate data
XMAX, XMIN; YMAX, YMIN	Maximum, minimum of X;Y scale
XSTART, YSTART	Starting value of X,Y scale plotting
XT, YT	Starting X,Y coordinates to write figure title or subtitle
YA, YB, YC	First, second, third curve Y coordinate data

Table 10. Definitions of symbols used in subroutine FGDA3

Symbol	Description
TD1, TD2, ... TD31	Data recorded on tape 1
X(I), Y(I); X(I), YB(I); X(I), YC(I)	Data to be used to plot curve 1, 2, 3
XD, YDA, YDB, YDC	X(I), YA(I), YB(I), YC(I) data read from tape 1
XDR, YDAR, YDBR, YDCR	Conversion factor of XD, YDA, YDB, YDC

Table 11. Definitions of symbols used in subroutine FGMN3

Symbol	Description
ABSDA, ABSDB, ABSDC	Absolute value of difference of maximum and minimum values of Y coordinates for curve 1, 2, 3
CXM, CXN	Maximum, minimum computed value of X
CYAM, CYAN; CYBM, CYBN; CYCM, CYCN	Maximum, minimum computed value of Y for curve 1, 2, 3
NGNB, NGNC	Control number used in computing scale ratio for 2, 3 curves
NYDRBA, NYDRCA	Integer ratio of ABSDB to ABSDA, ABSDC to ABSDA
YAM, YAN; YBM, YBN; YCM, YCN	Maximum, minimum YA, YB, YC
YBMN, YBMX; YCMN, YCMX	Converted minimum, maximum YB; YC used in scale computation
YDRBA, YDRCA	Ratio of ABSDB to ABSDA, ABSDC to ABSDA
YYLABEL	Y axis label for 2 or 3 curves

Table 12. Definitions of symbols used in subroutine FGPRTCV

Symbol	Description
CURVE	Array name of curve symbols used to print curves
DX, DY	Number of units per inch of X, Y axis
DXIO, DYIO	Number of units per line in X, Y direction
FIELD	Field descriptor for printer plotting scale printout
FMTO, FMT1, FMT2, FMT3, FMT4, FMT5	Format number for printer plotting label formats
N	Number of data
NTX, NTXX	Number of spaces in printer plotting title and subtitle printout
NX, NY	X, Y number of symbols used in printer plotting
NXX	Number of X scale values
XSN	X scale values

Table 13. Definitions of symbols used in subroutine FGPRTSB

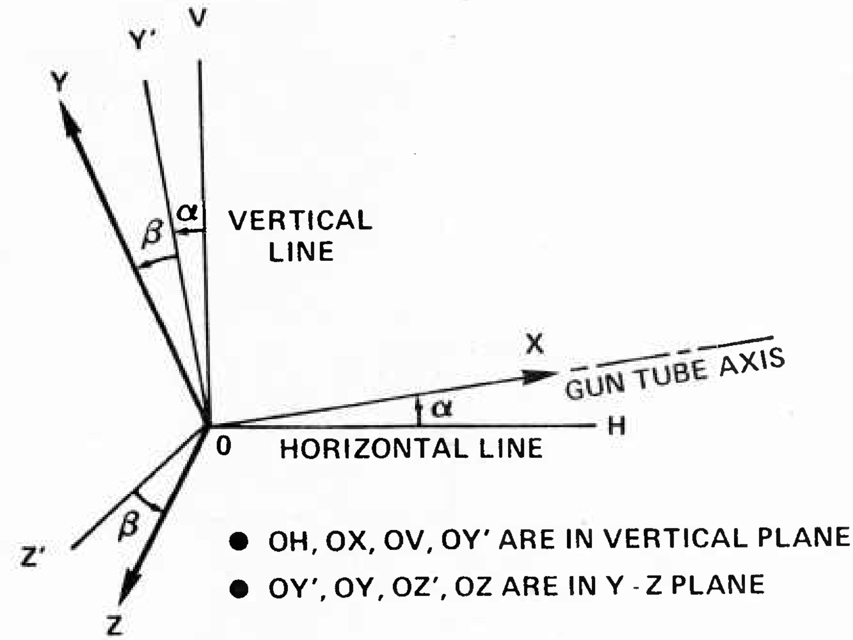
Symbol	Description
BAR	Symbol of curve, —
BLANK	Symbol of curve for no plotting
CVSBL	Array name of symbols of different printer curves; CVSBL(1) = A, CVSBL(2) = B, CVSBL(3) = C
L	Line number
LN	Scale-annotation line number
LX	Symbol position index number
NC	Curve index number
STAR	Curve symbol determined from CVSBL
VLINE	Curve symbol for vertical line

Table 14. Definitions of symbols used in subroutine FGSTRT

Symbol	Description
D, DX	Units of scale per unit length of scale
MX	Flag number to indicate whether maximum and minimum values are given (when MX = 1) or computed values in the program (MX = 0) are used
XMAX, XX(2)	Maximum value of scale
XMIN, XX(1)	Minimum value of scale
XSIZE, SIZE	Size or length of axis
XSTART, START	Starting value of axis scale

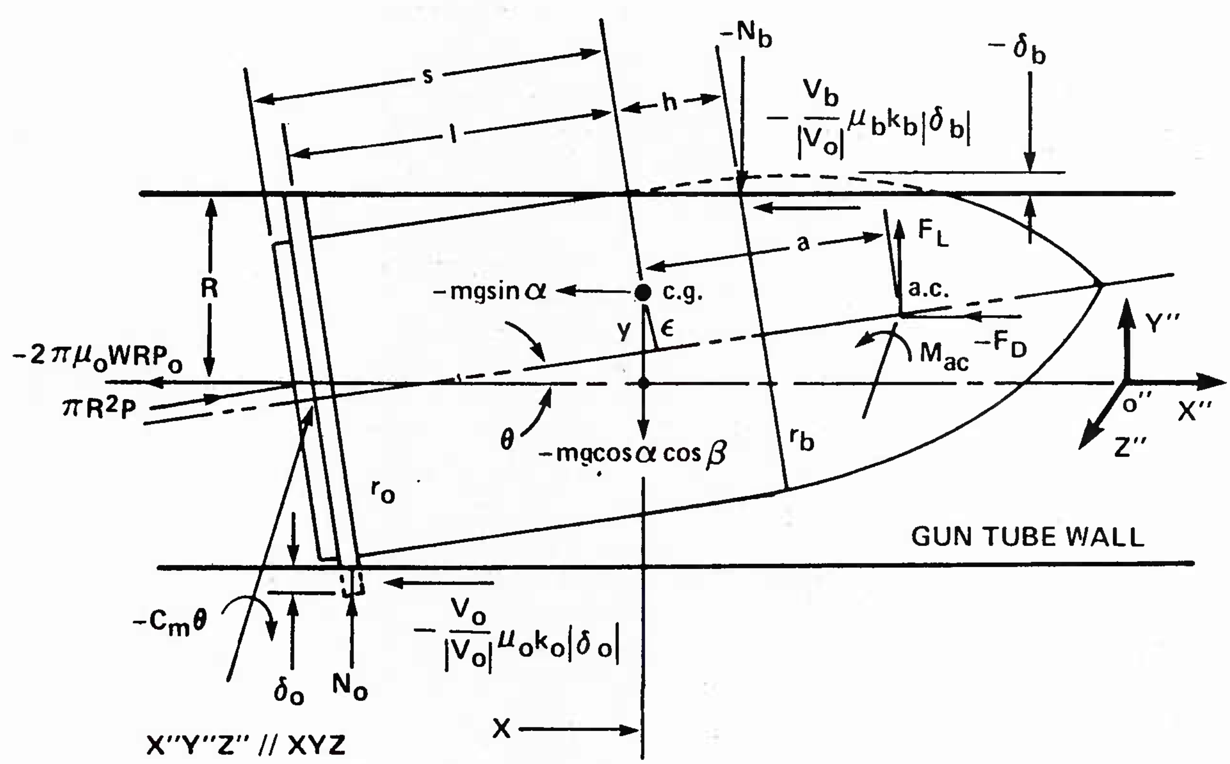
Table 15. Definitions of symbols used in subroutine OPDTA

Symbol	Description
DA, DB, DC, DD, DE, DF, DG, DH, DI, DJ	Intermediate symbols for coverting English units to metric units of data
NO	Data number



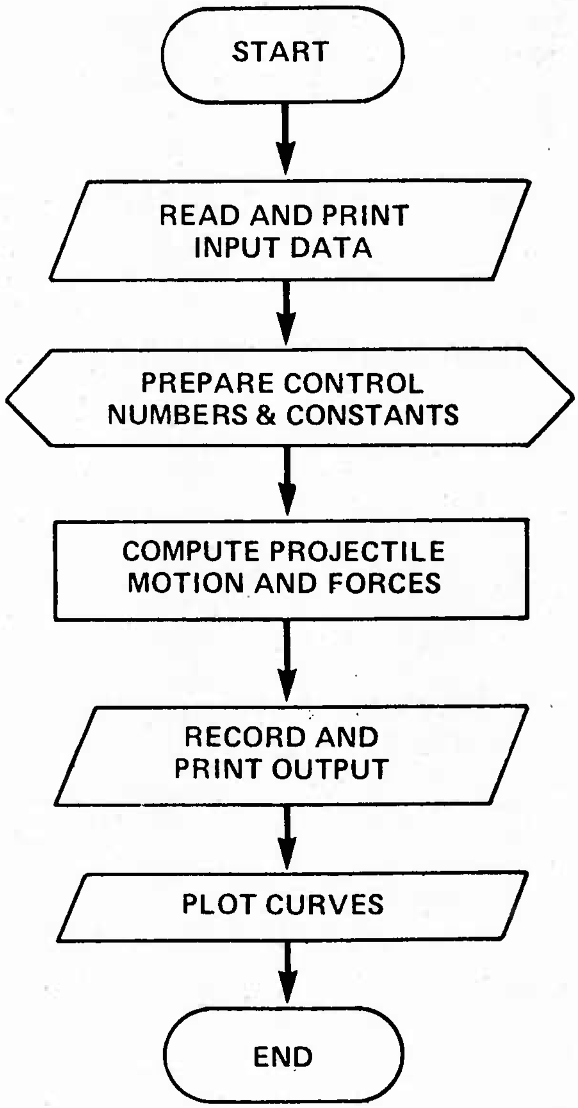
Coordinate System XYZ

Figure 1



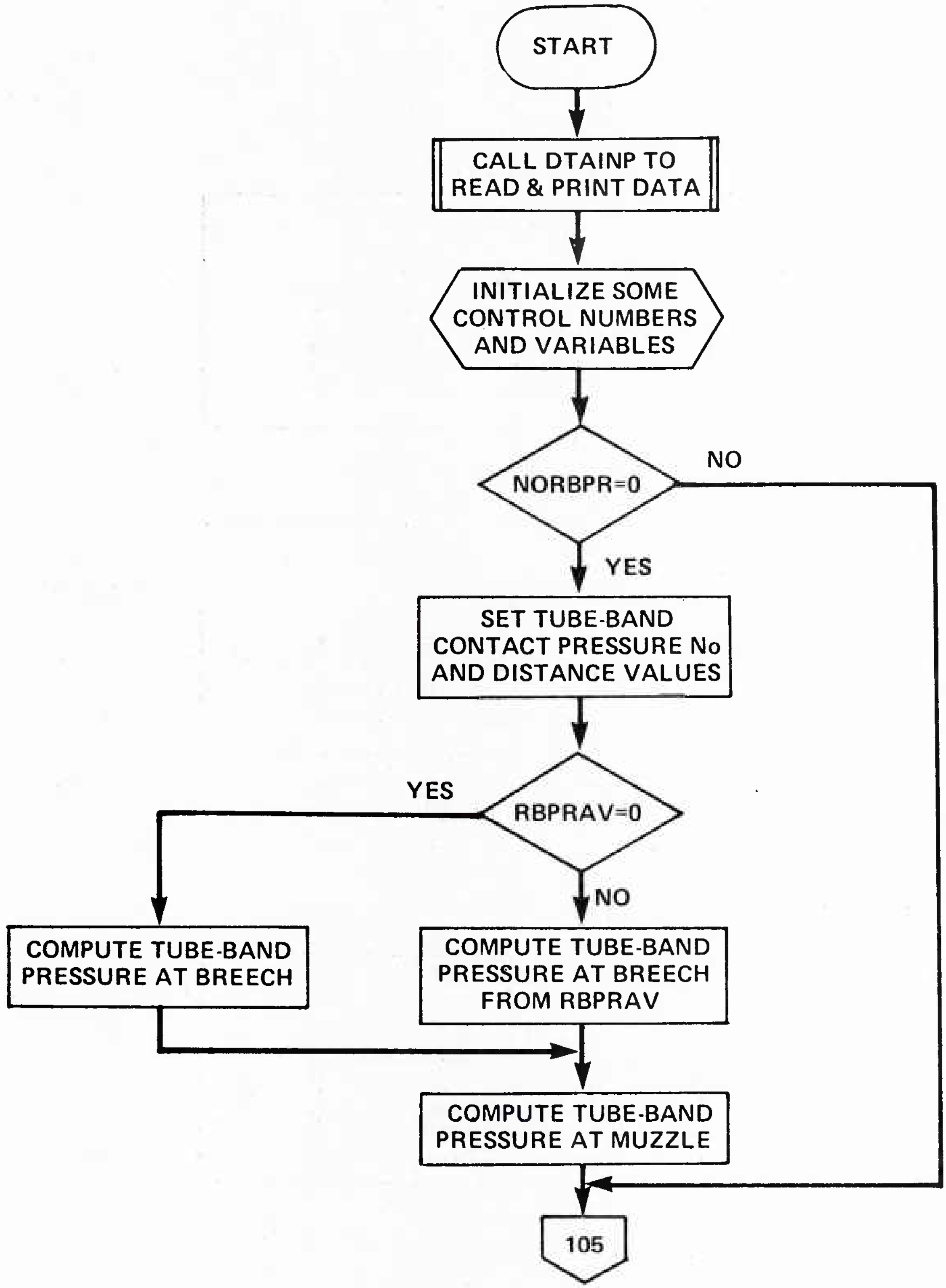
Forces and Moments

Figure 2



Outline Flowchart of Program Ballot 2

Figure 3



Flowchart of Main Program

Figure 4

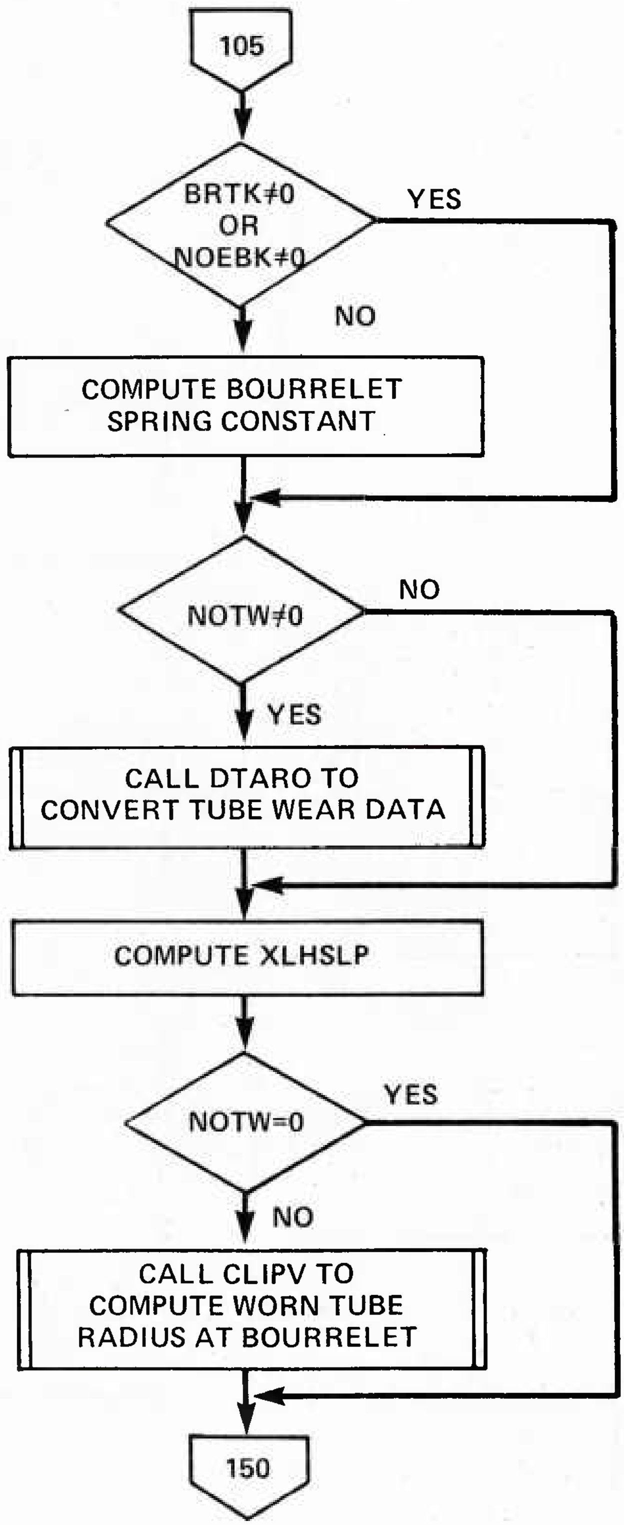
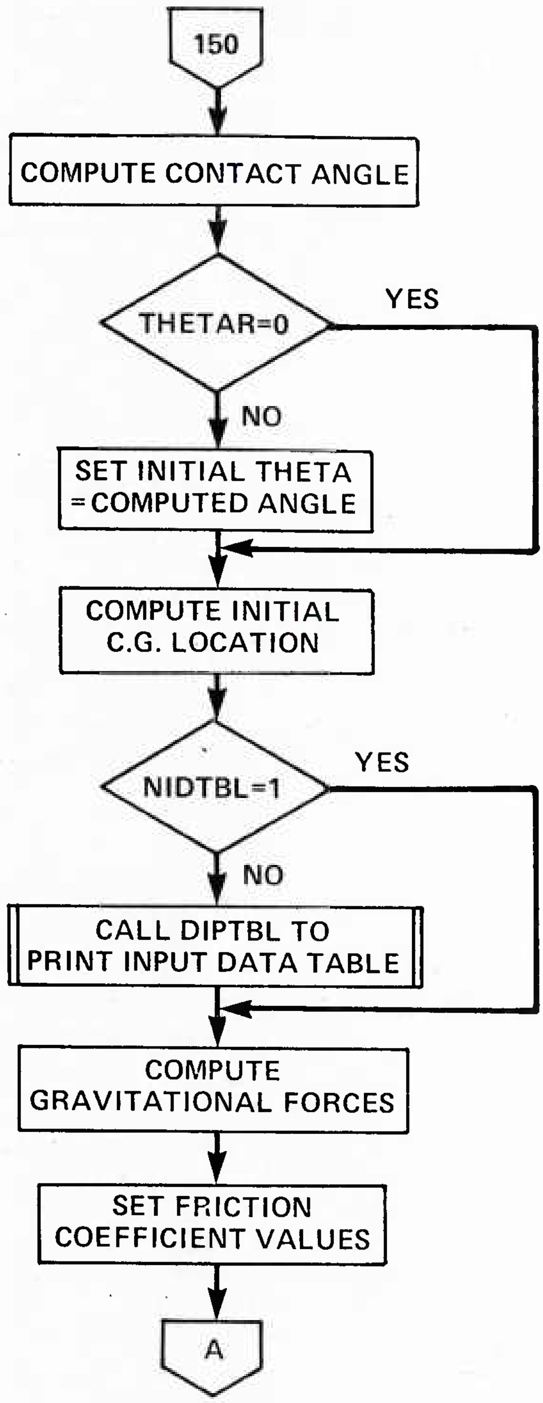


Figure 4 (Continued)



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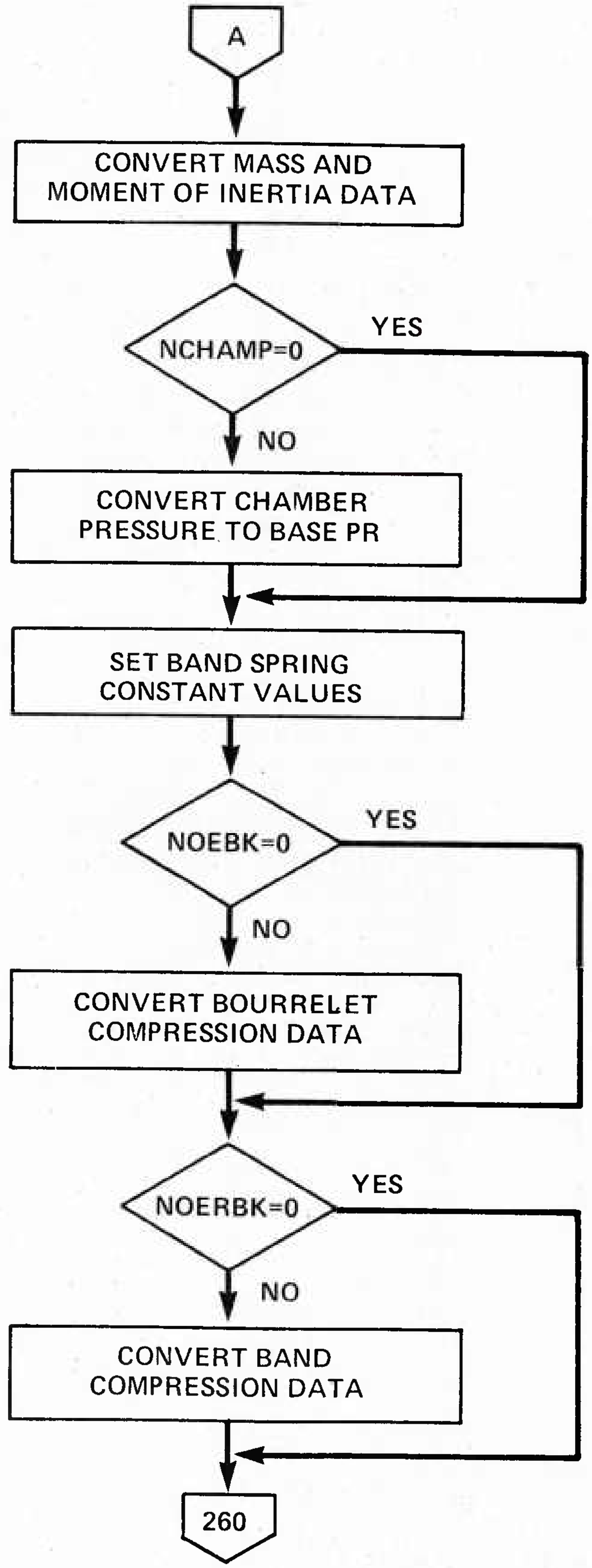
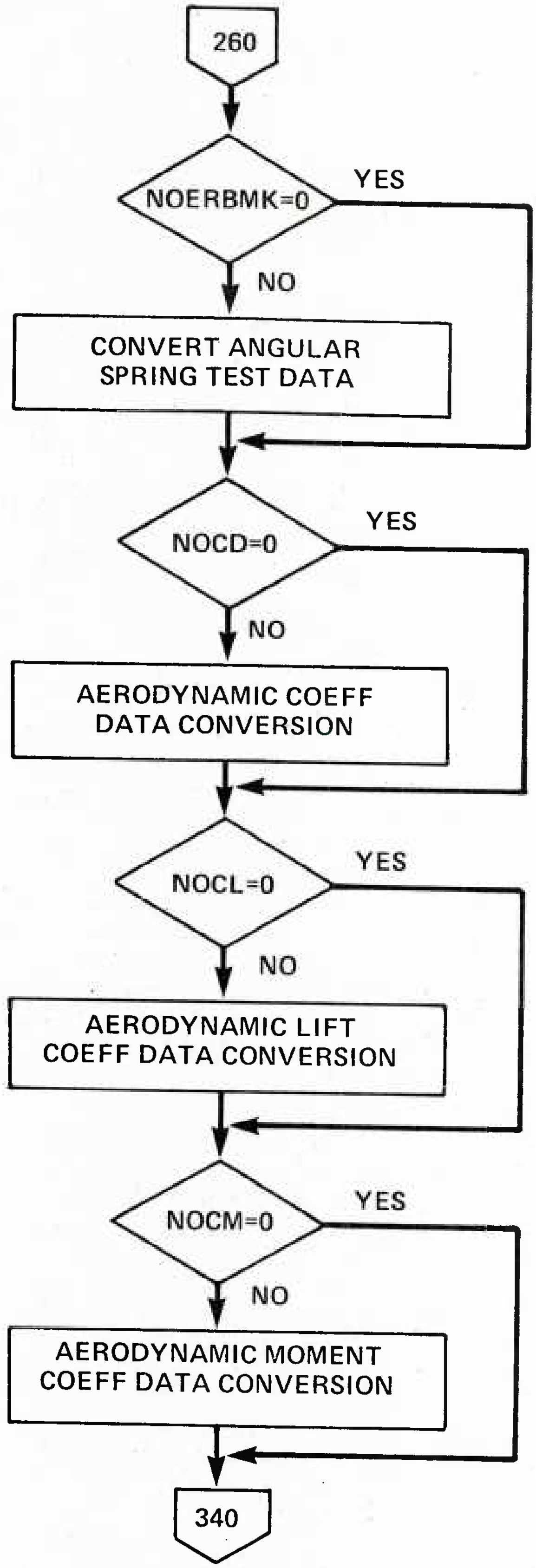


Figure 4 (Continued)



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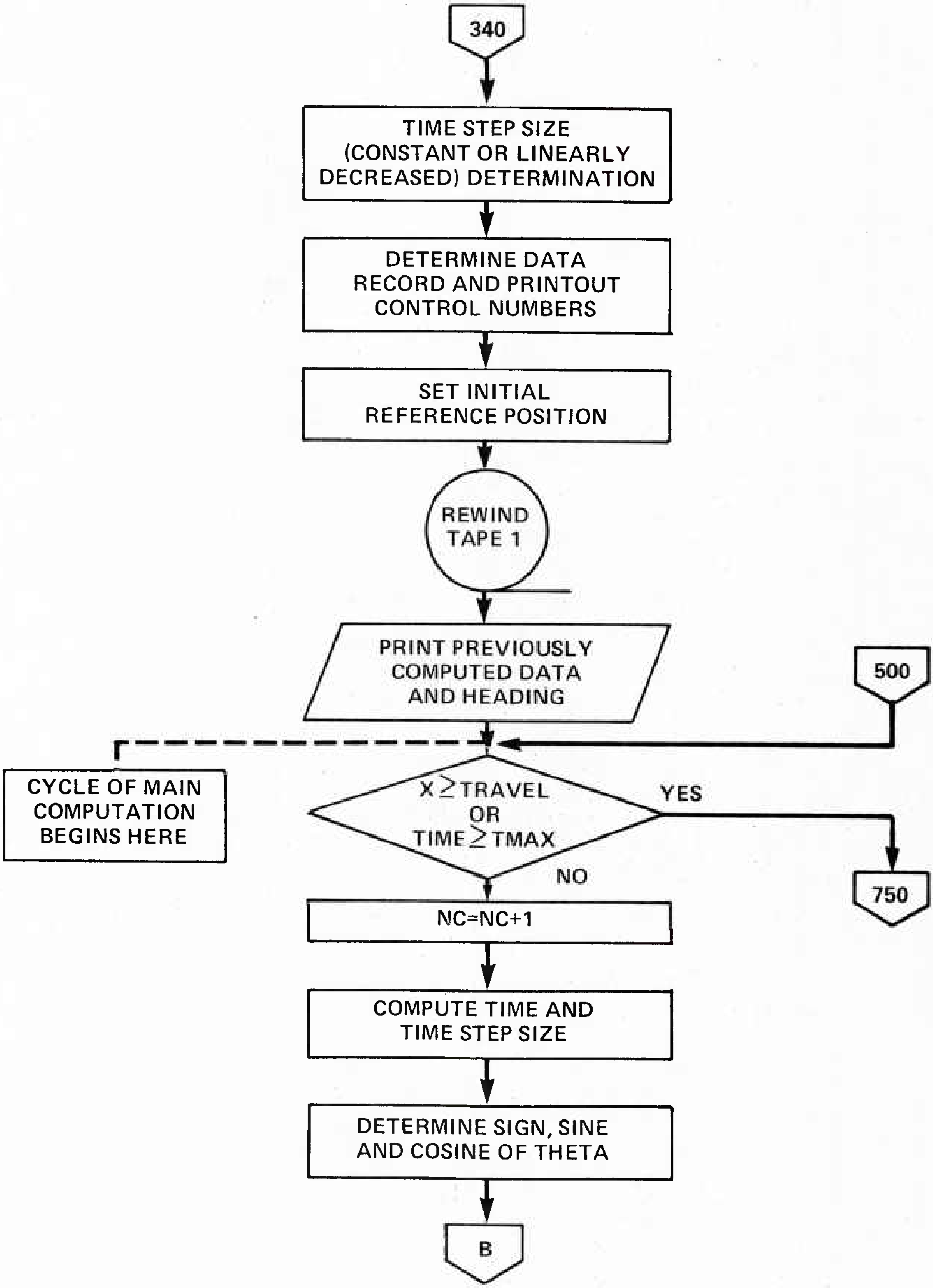

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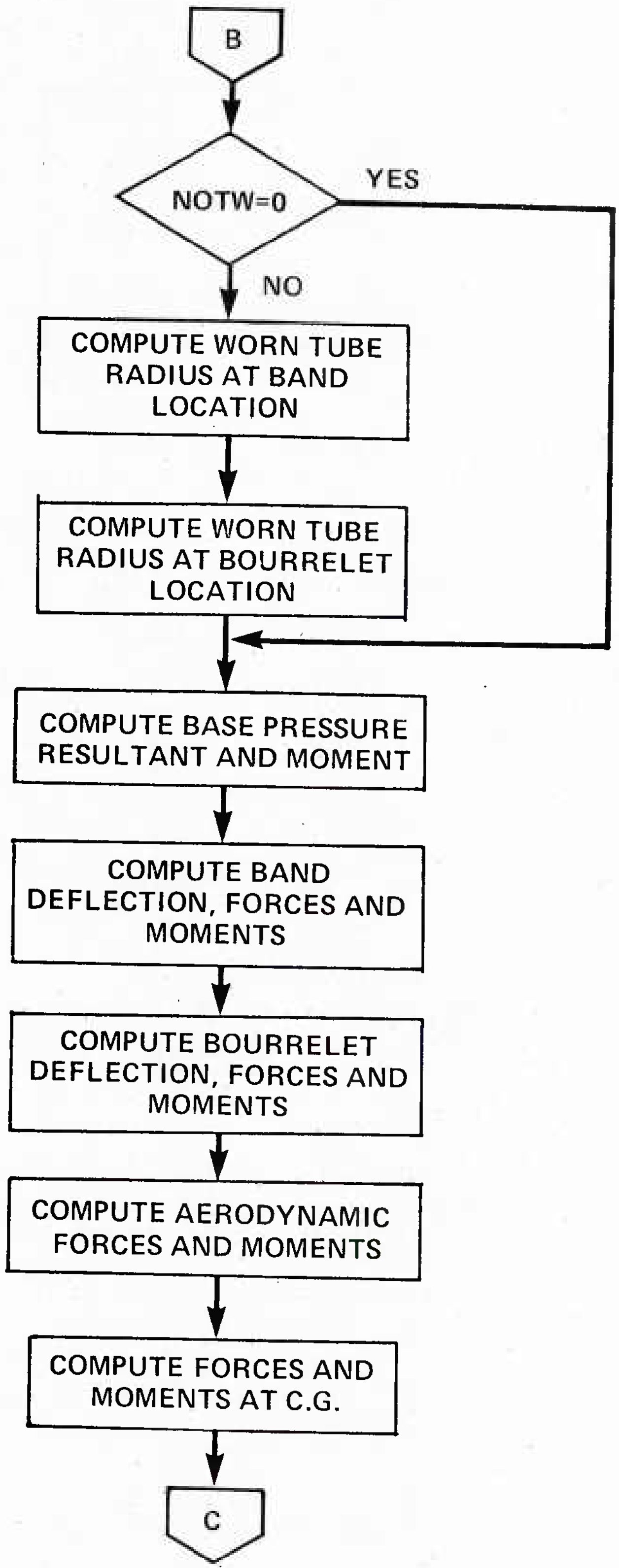

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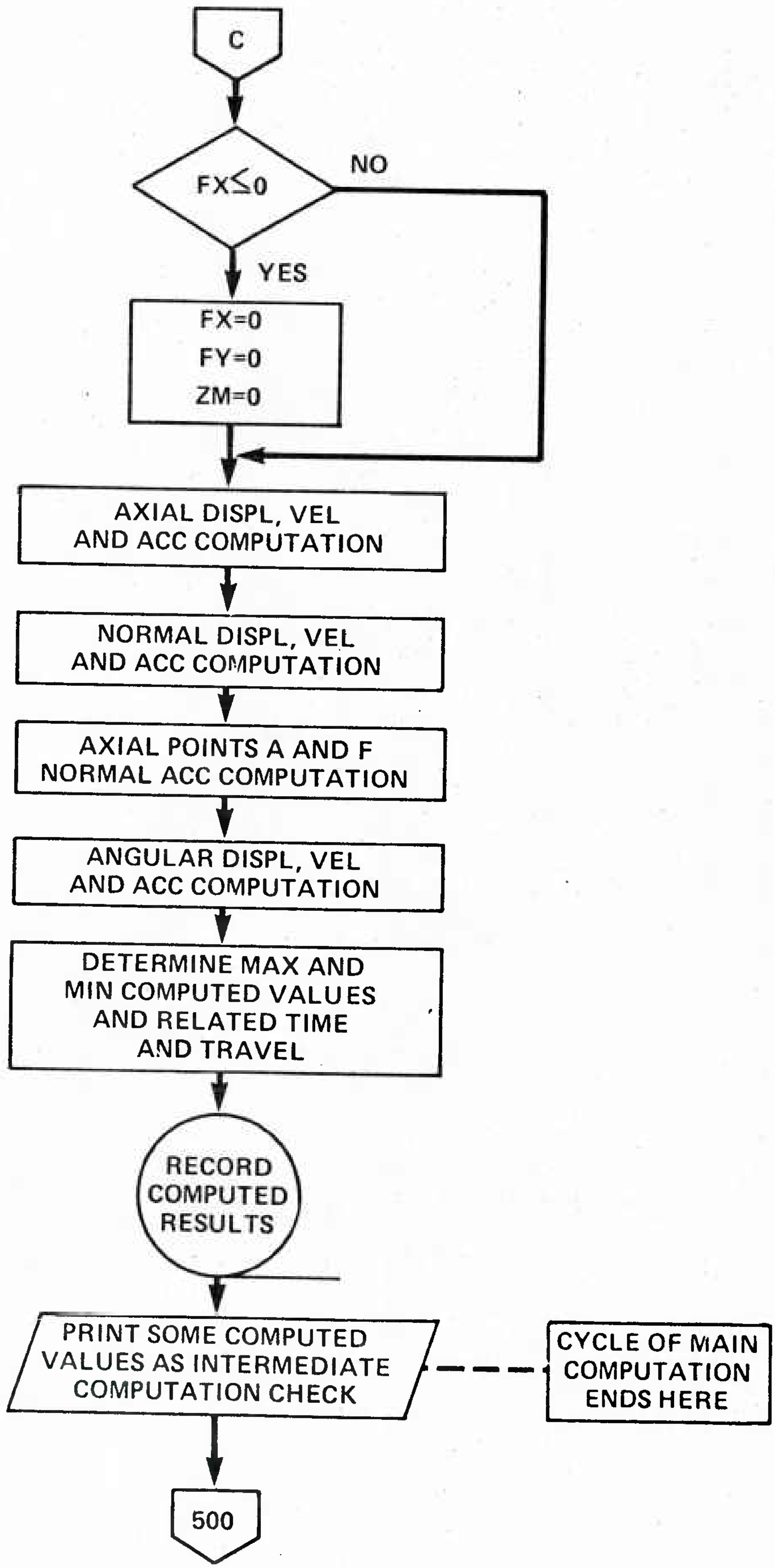

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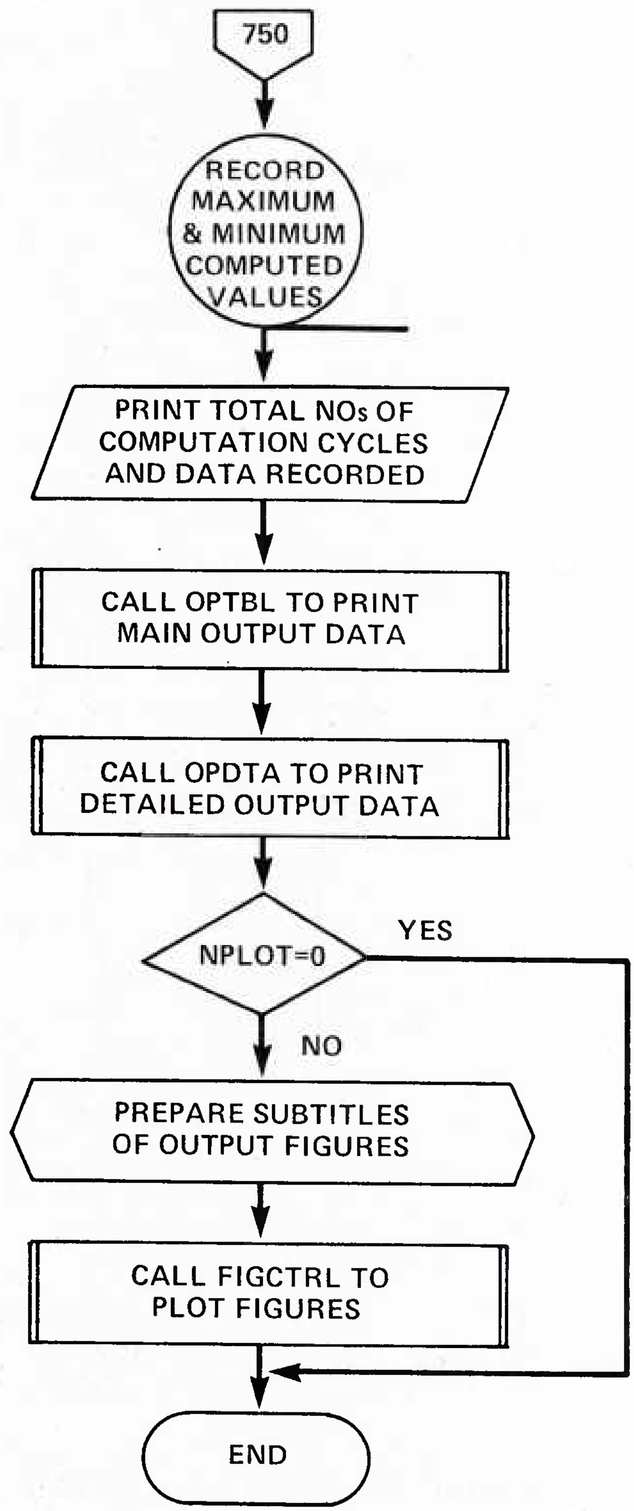

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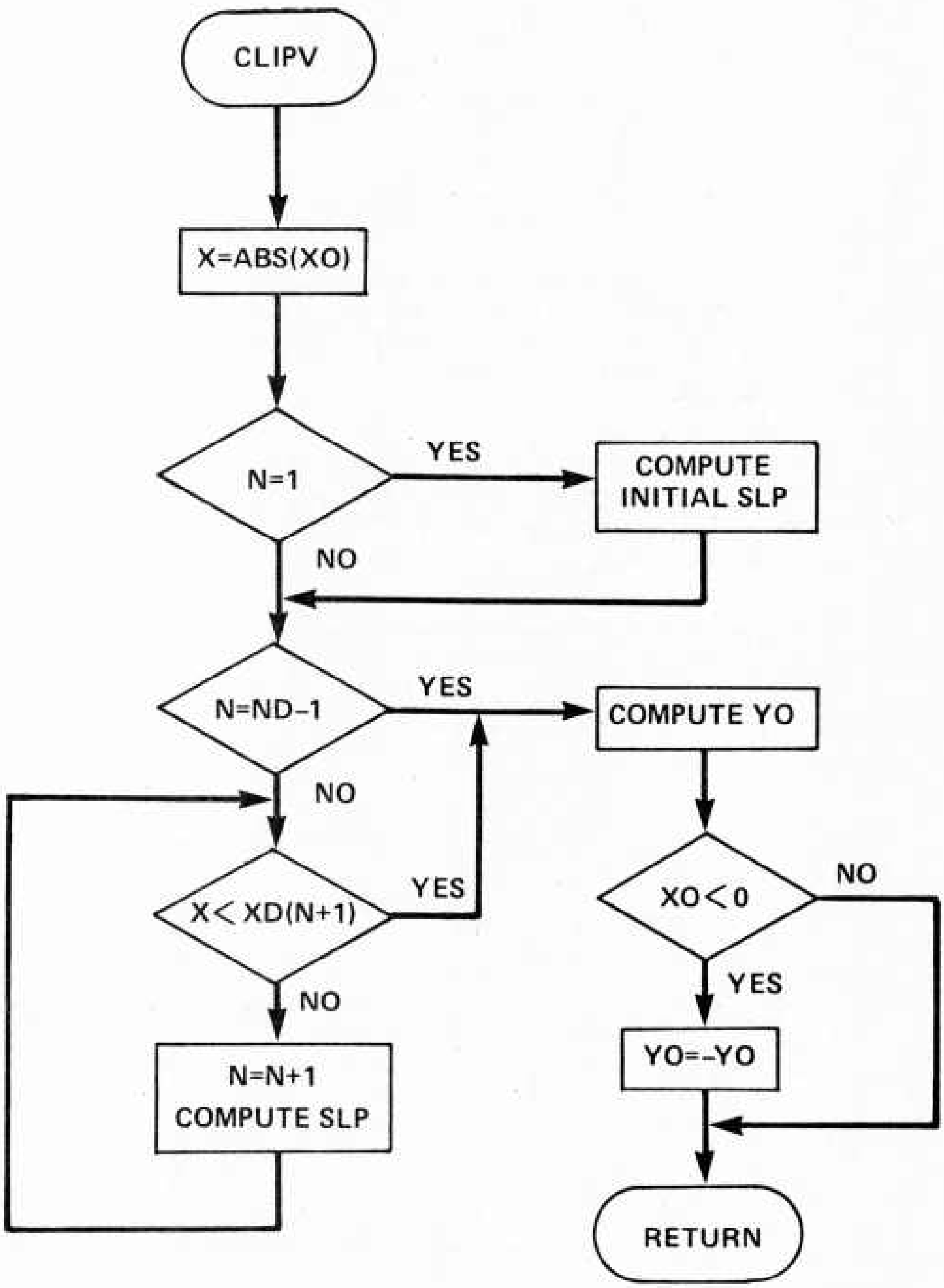
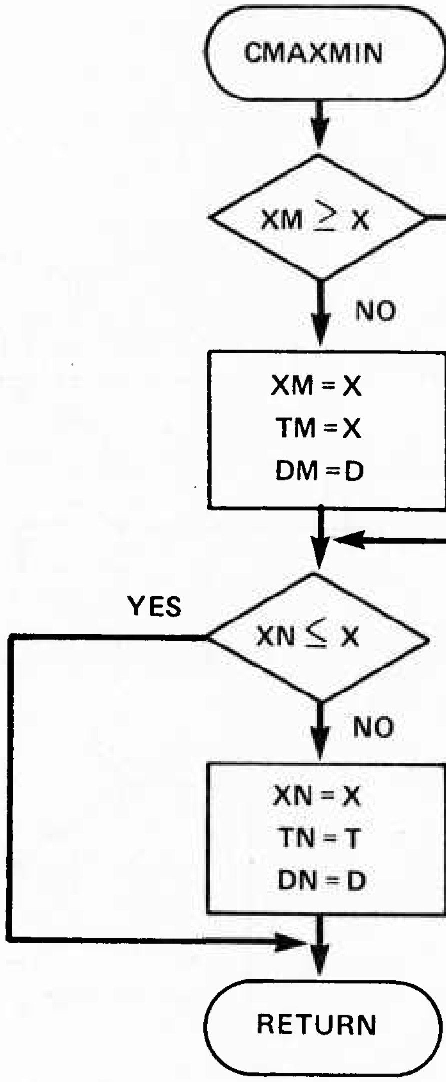


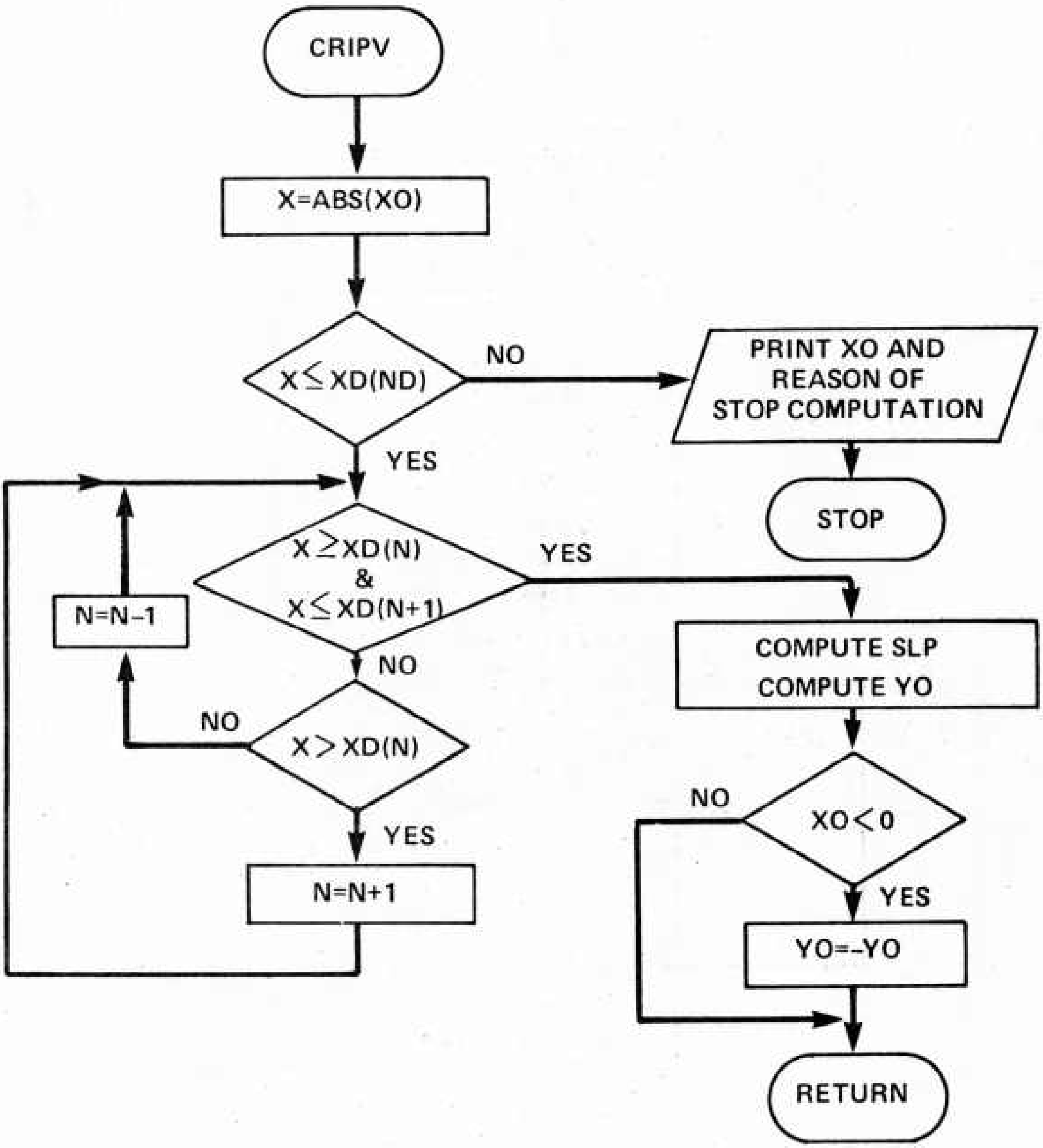
Flowchart of Subroutine CLIPV

Figure 5



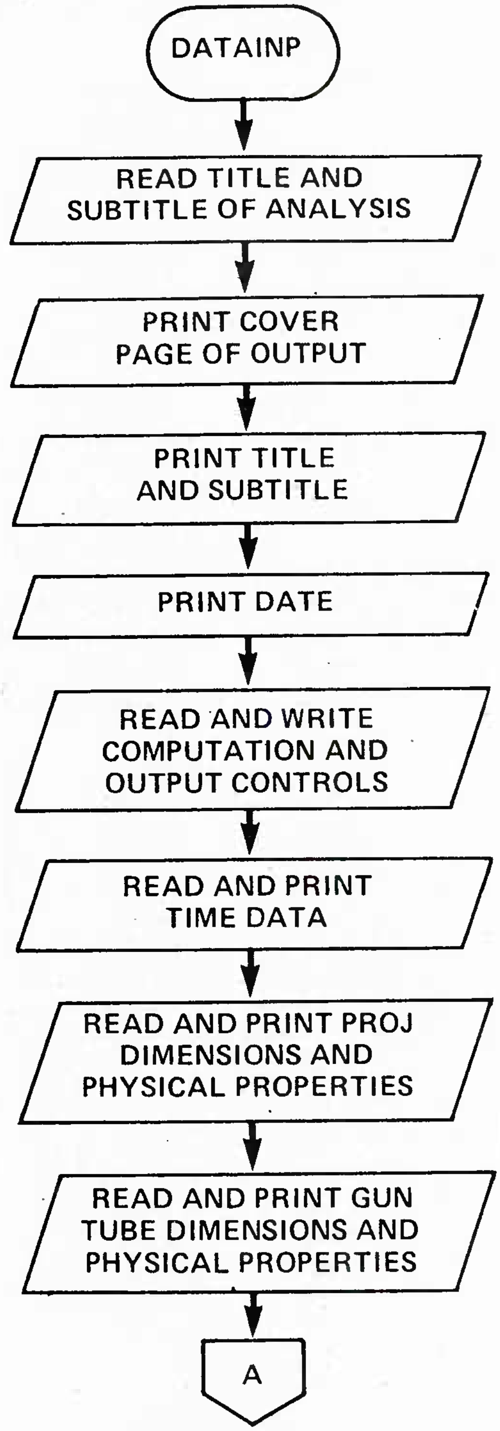
Flowchart of Subroutine CMAXMIN

Figure 6



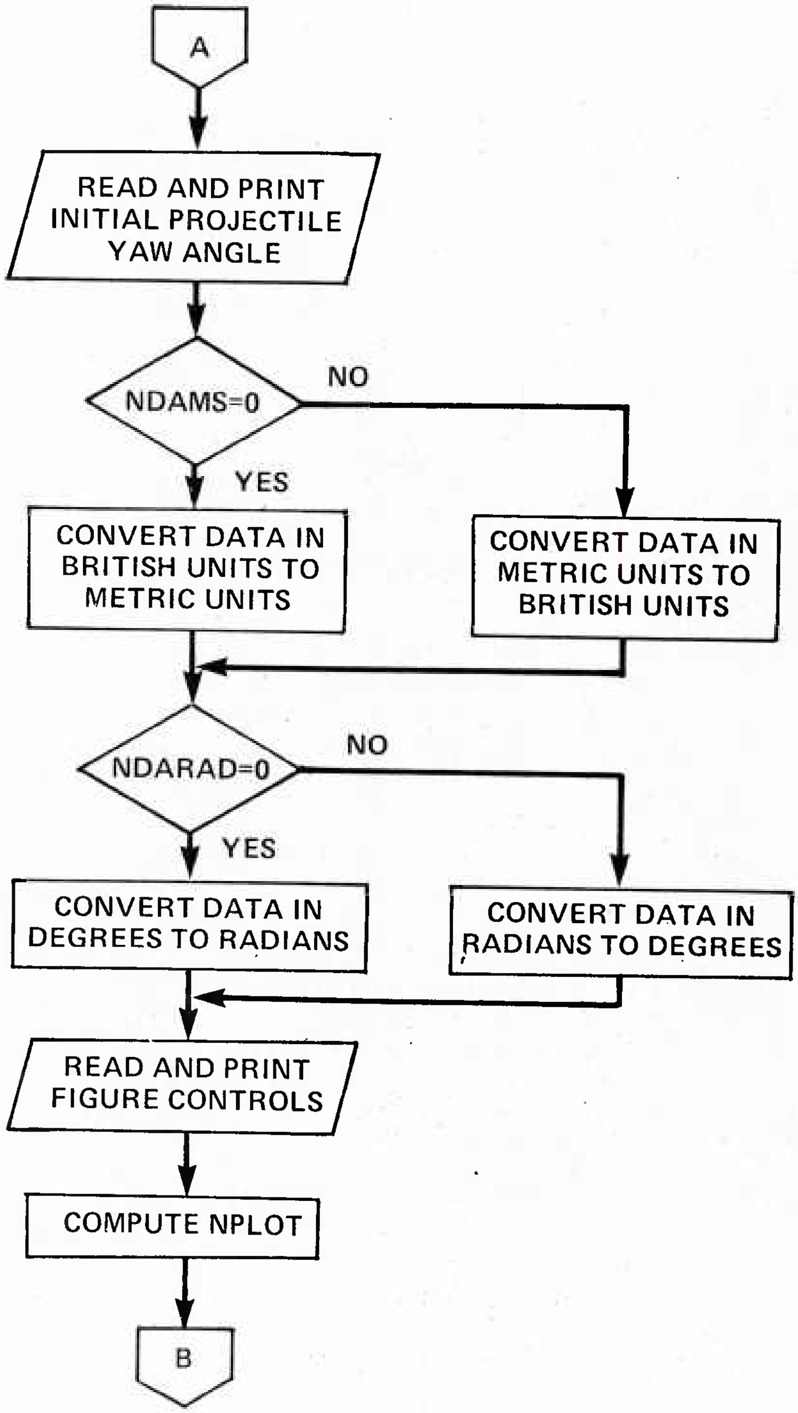
Flowchart of Subroutine CRIPV

Figure 7



Flowchart of Subroutine DATAINP

Figure 8



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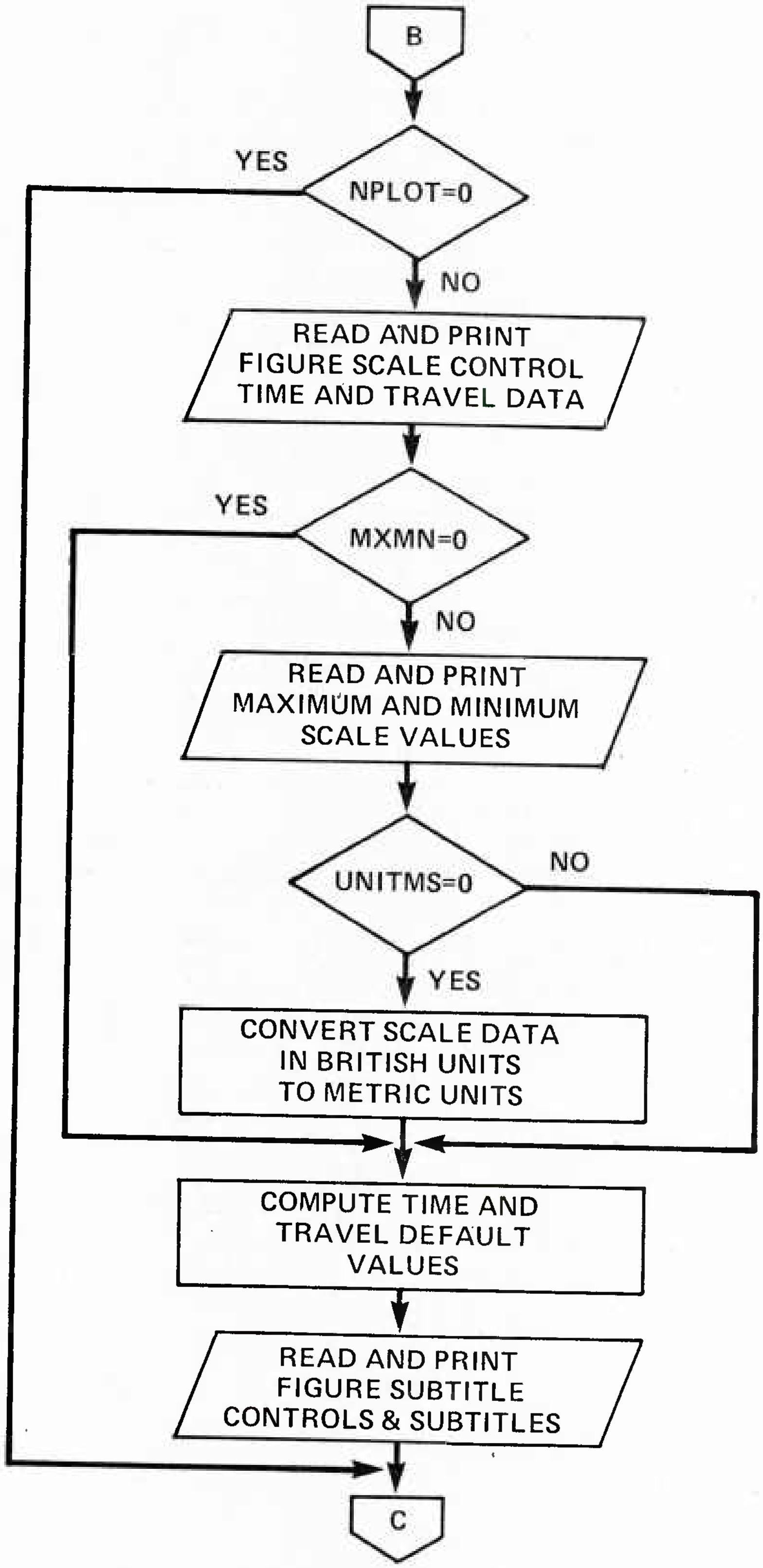

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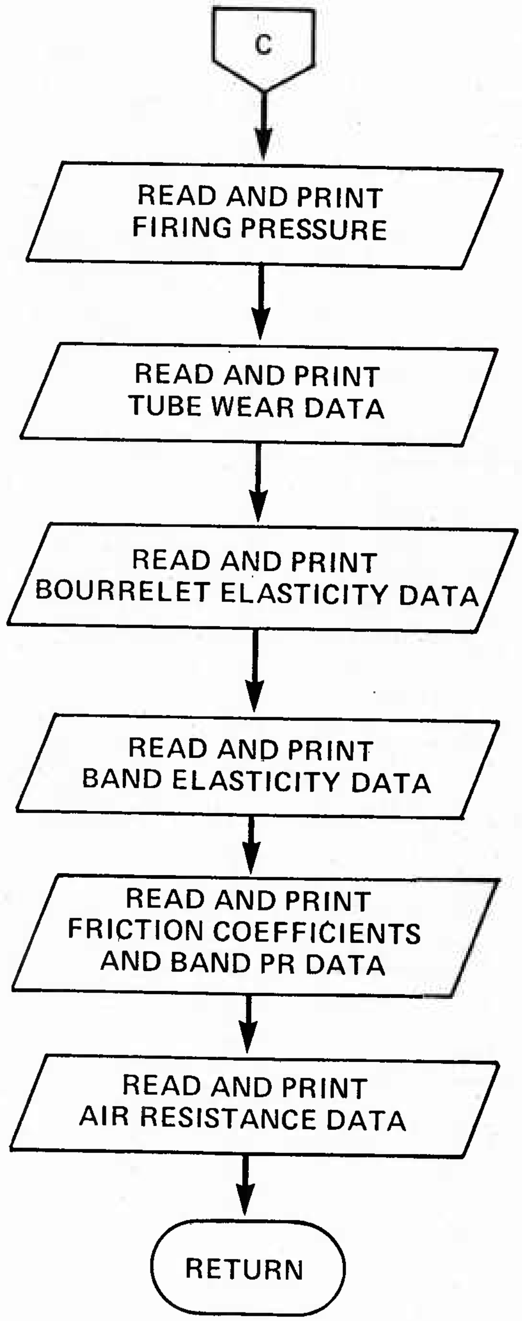

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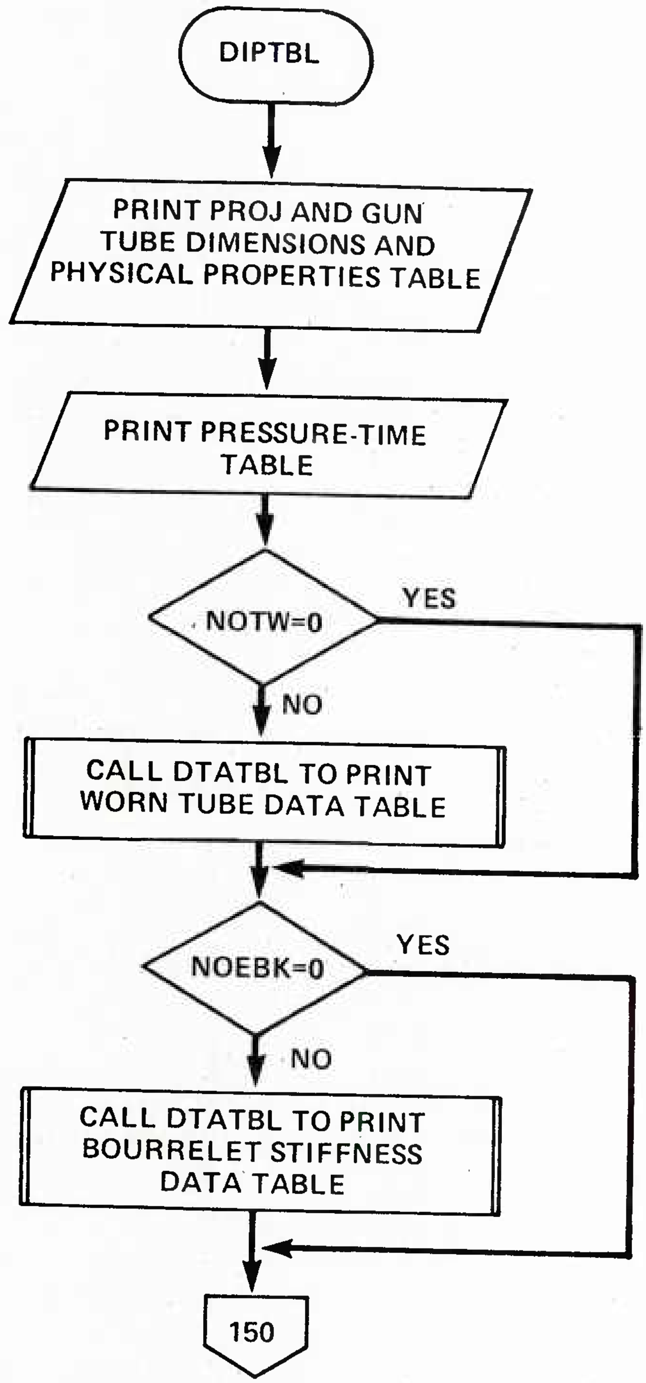


Flowchart of Subroutine DIPTBL

Figure 9

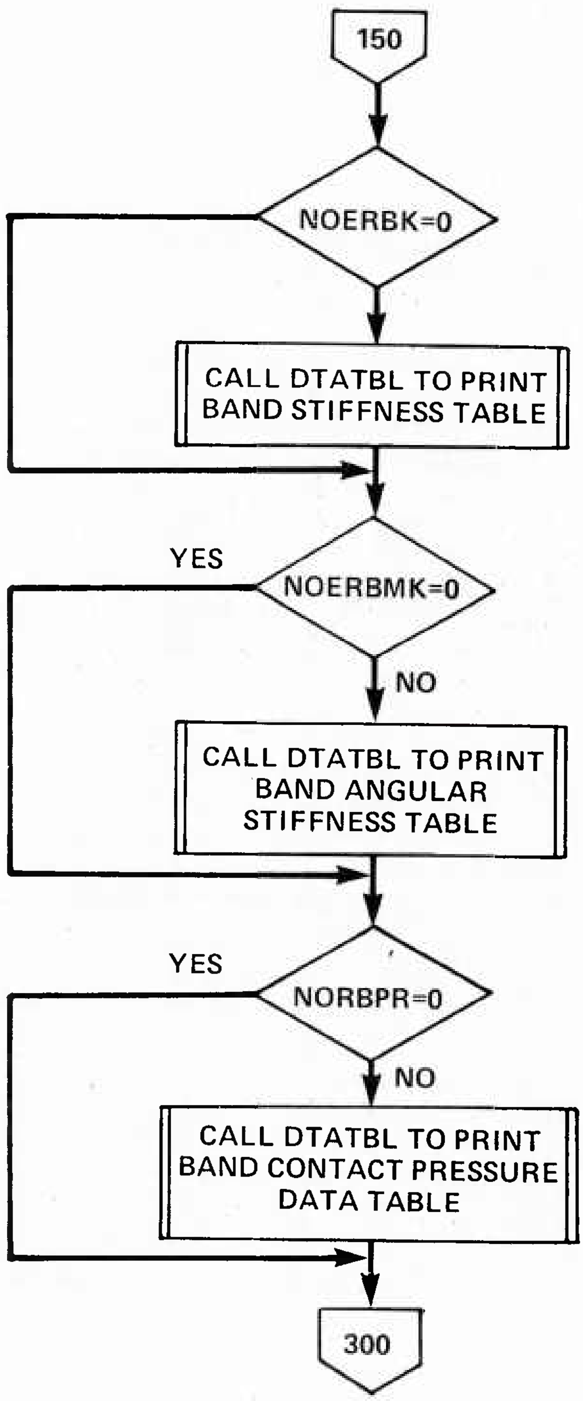


Figure 9 (Continued)

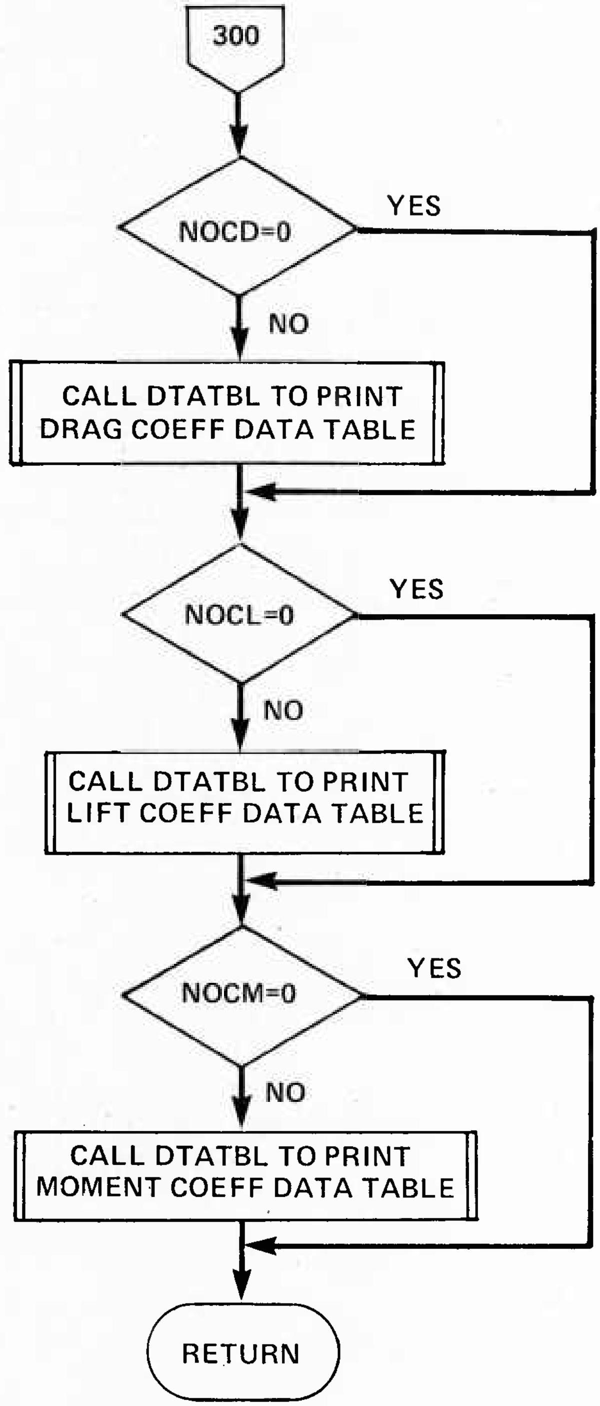
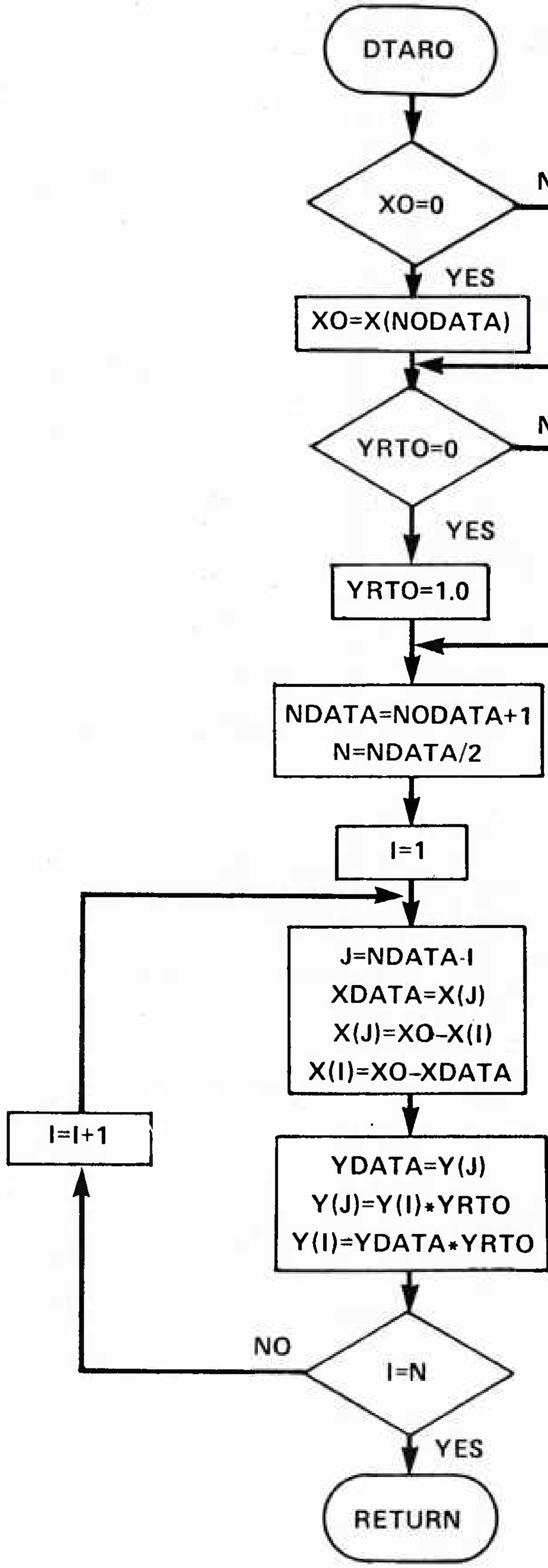
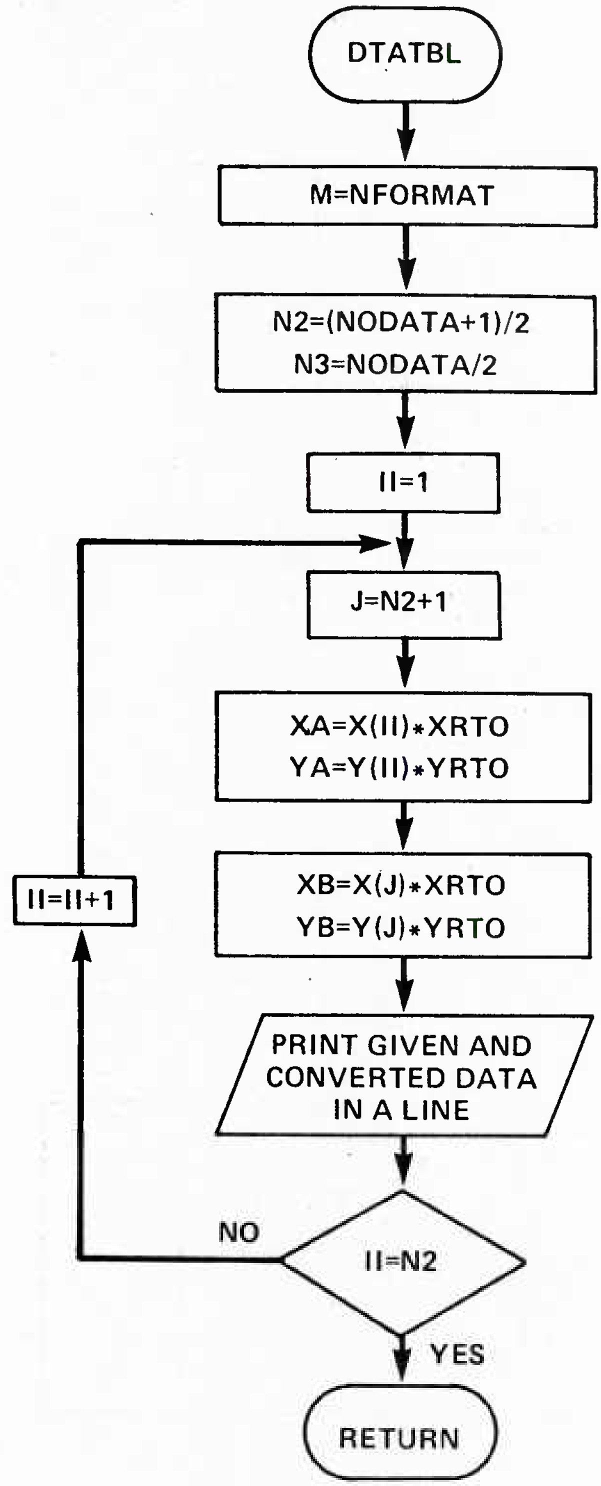


Figure 9 (Continued)



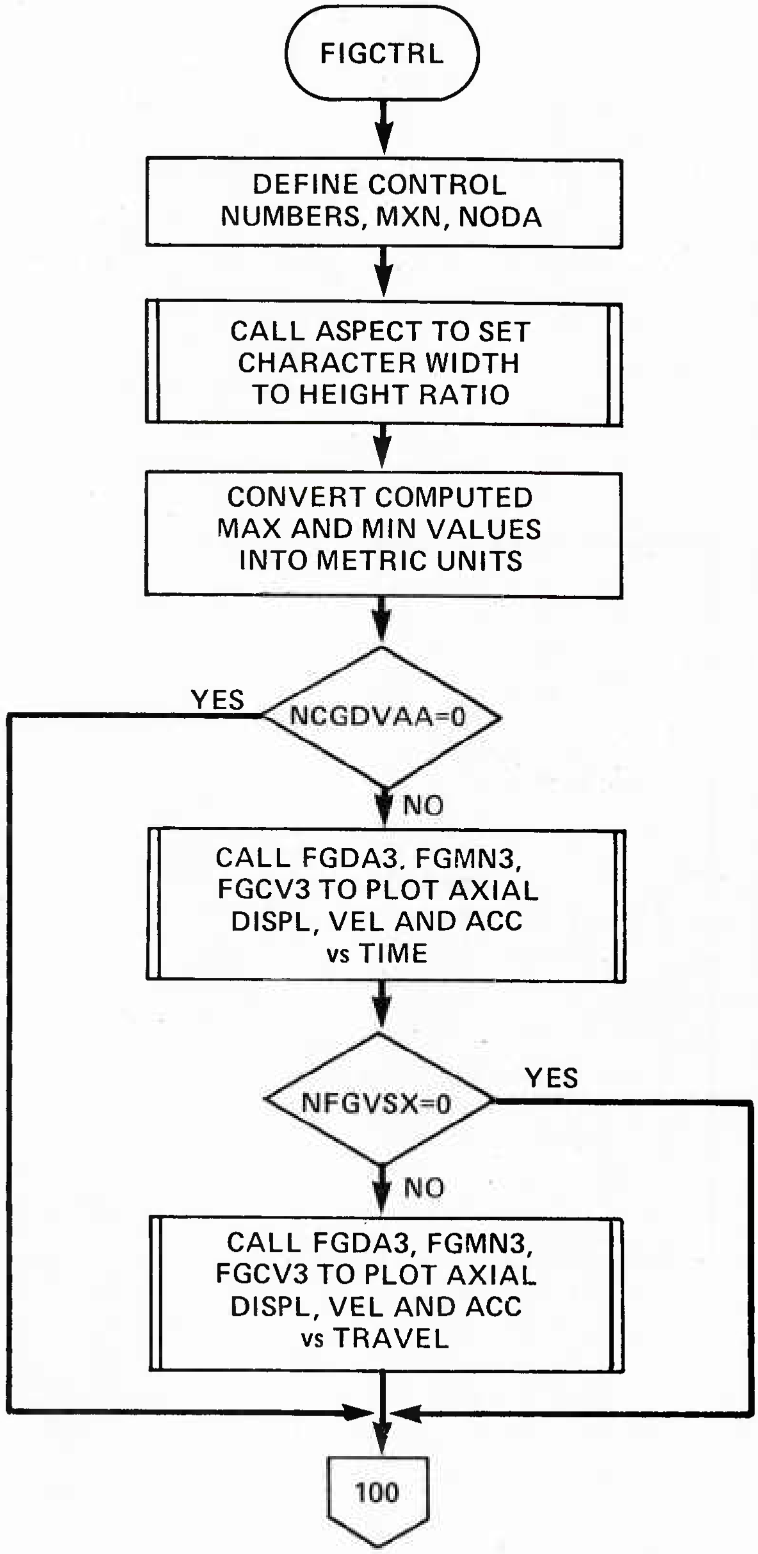
Flowchart of Subroutine DTARO

Figure 10



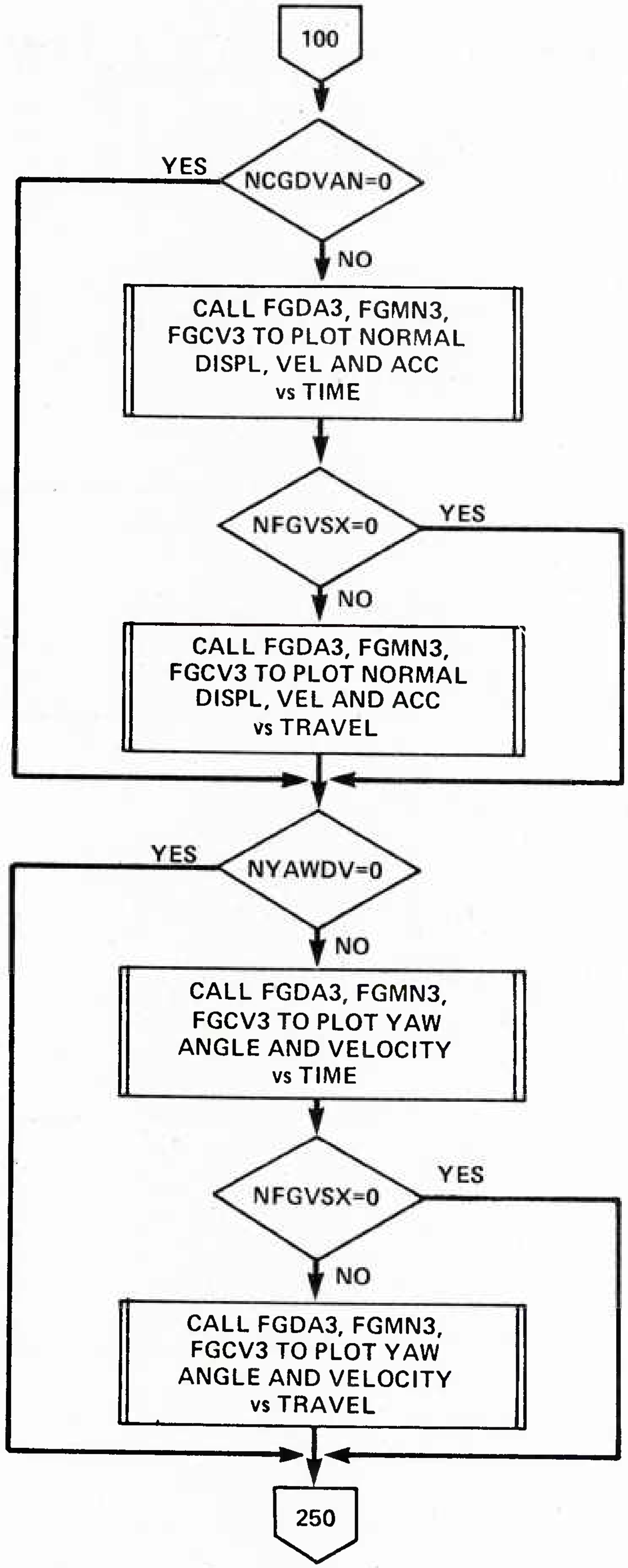
Flowchart of Subroutine DTATBL

Figure 11



Flowchart of Subroutine FIGCTRL

Figure 12



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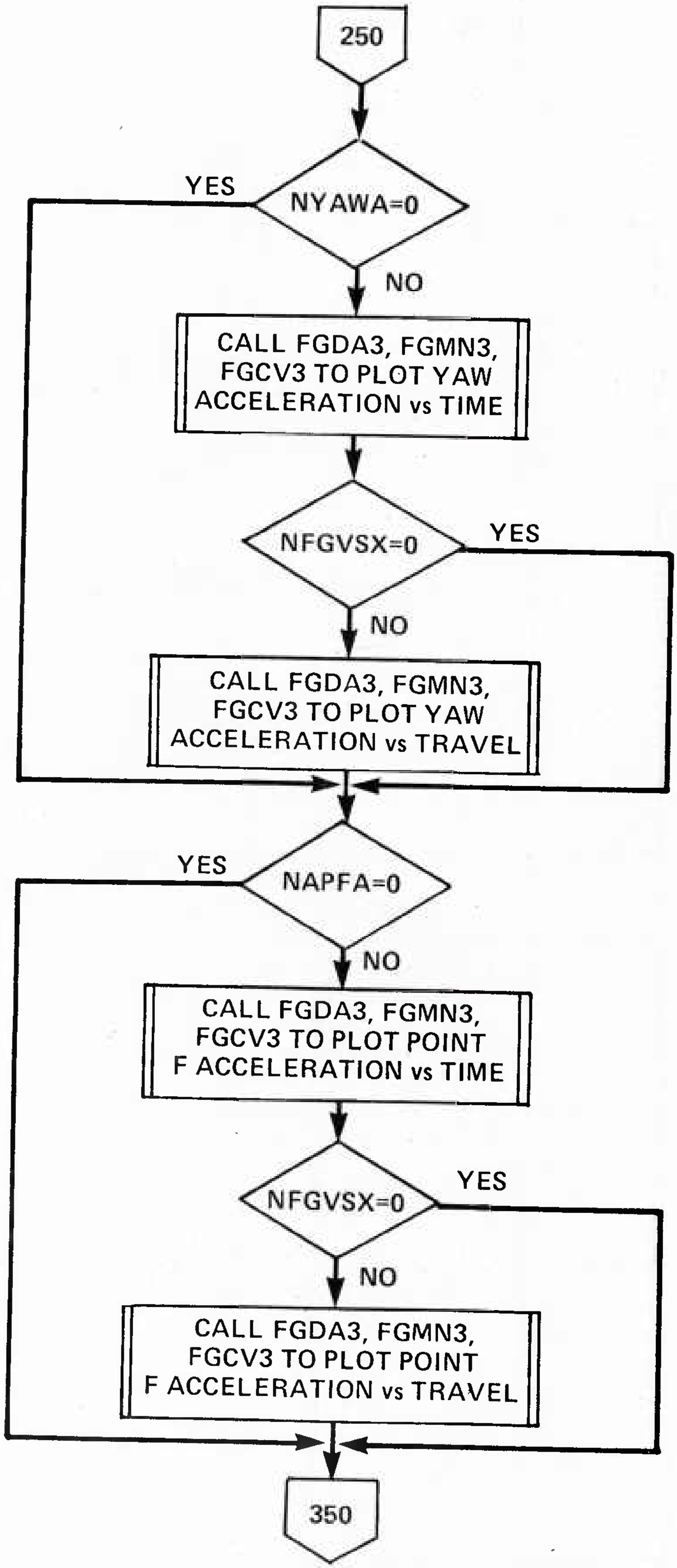

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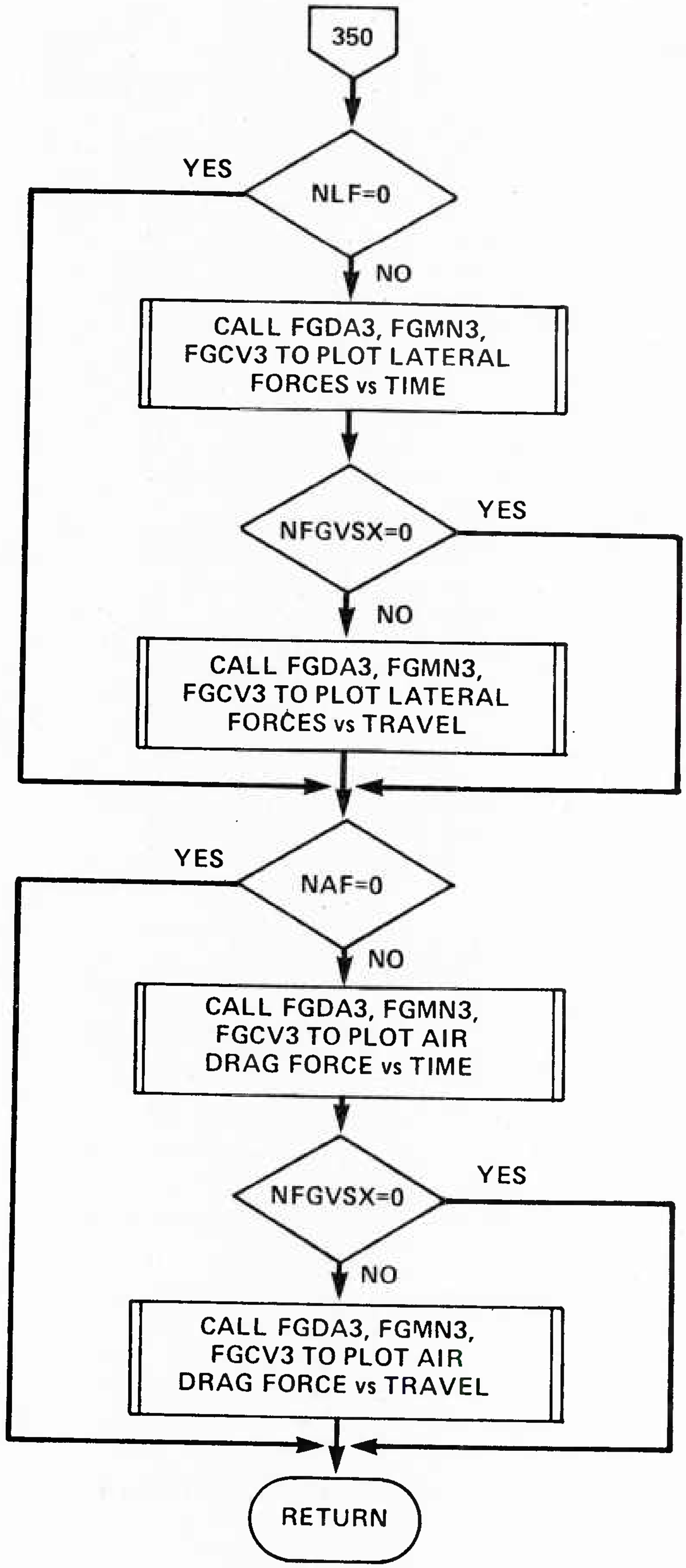

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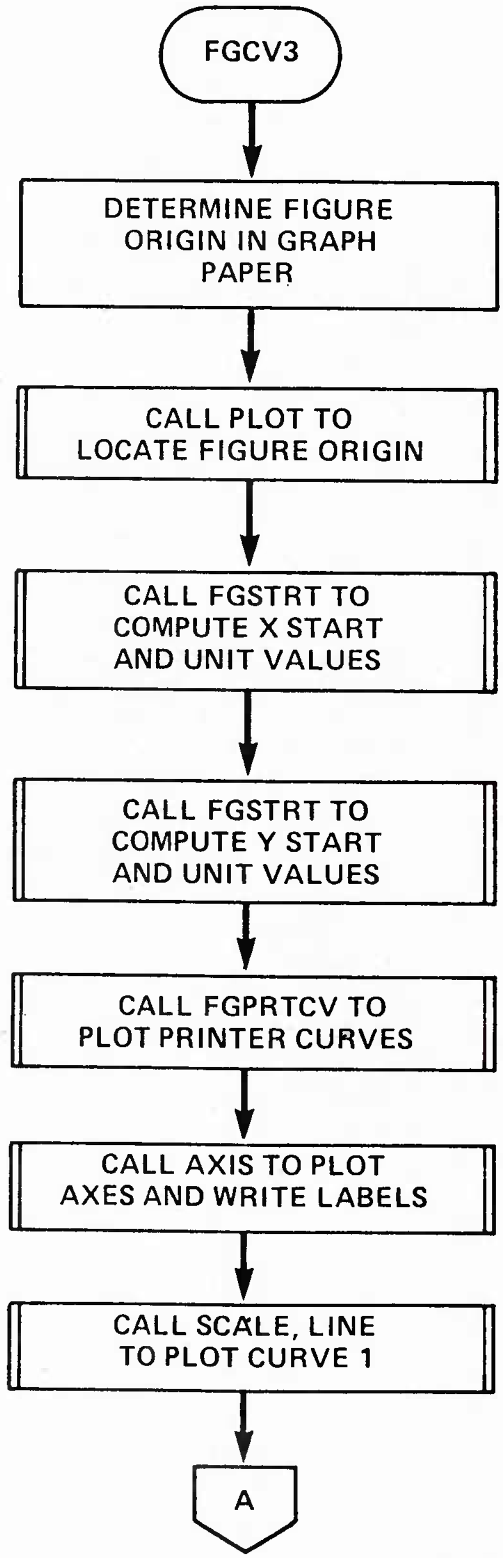


Flowchart of Subroutine FGCV3

Figure 13

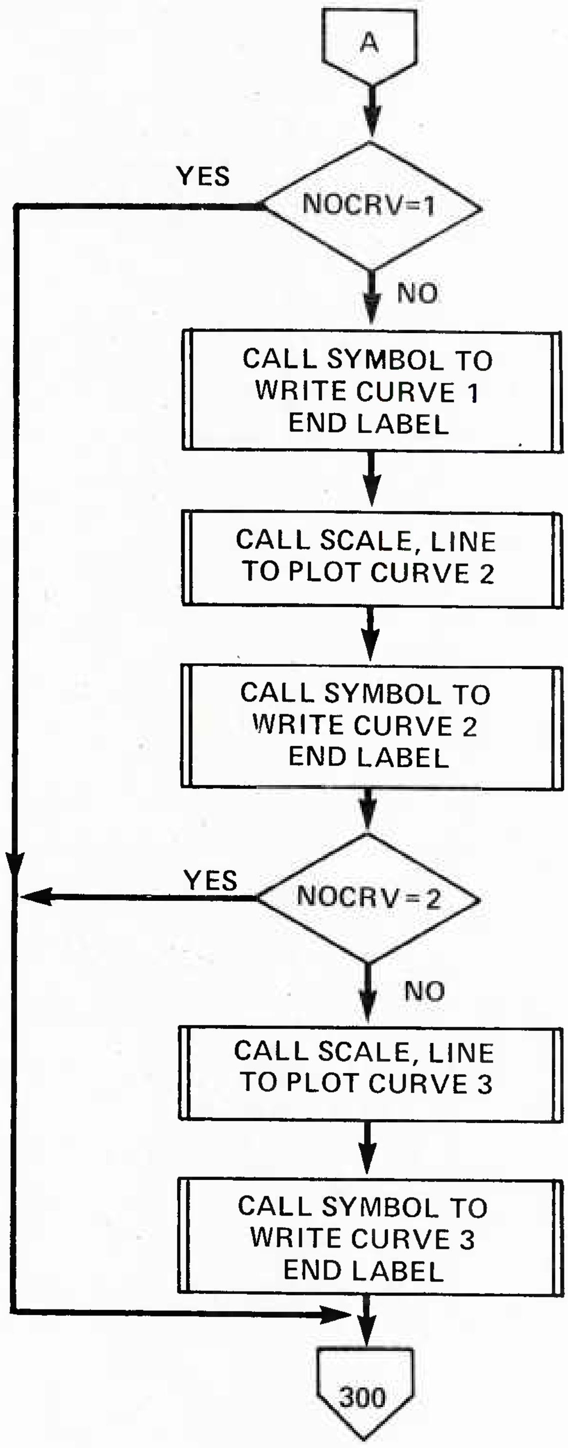


Figure 13 (Continued)

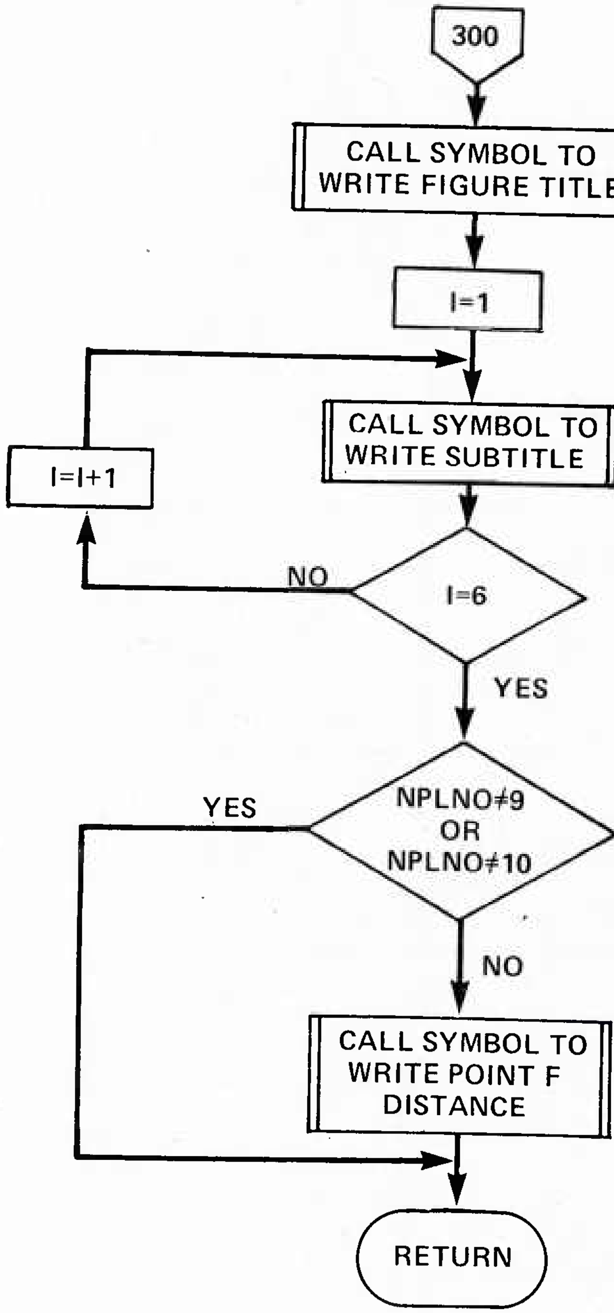
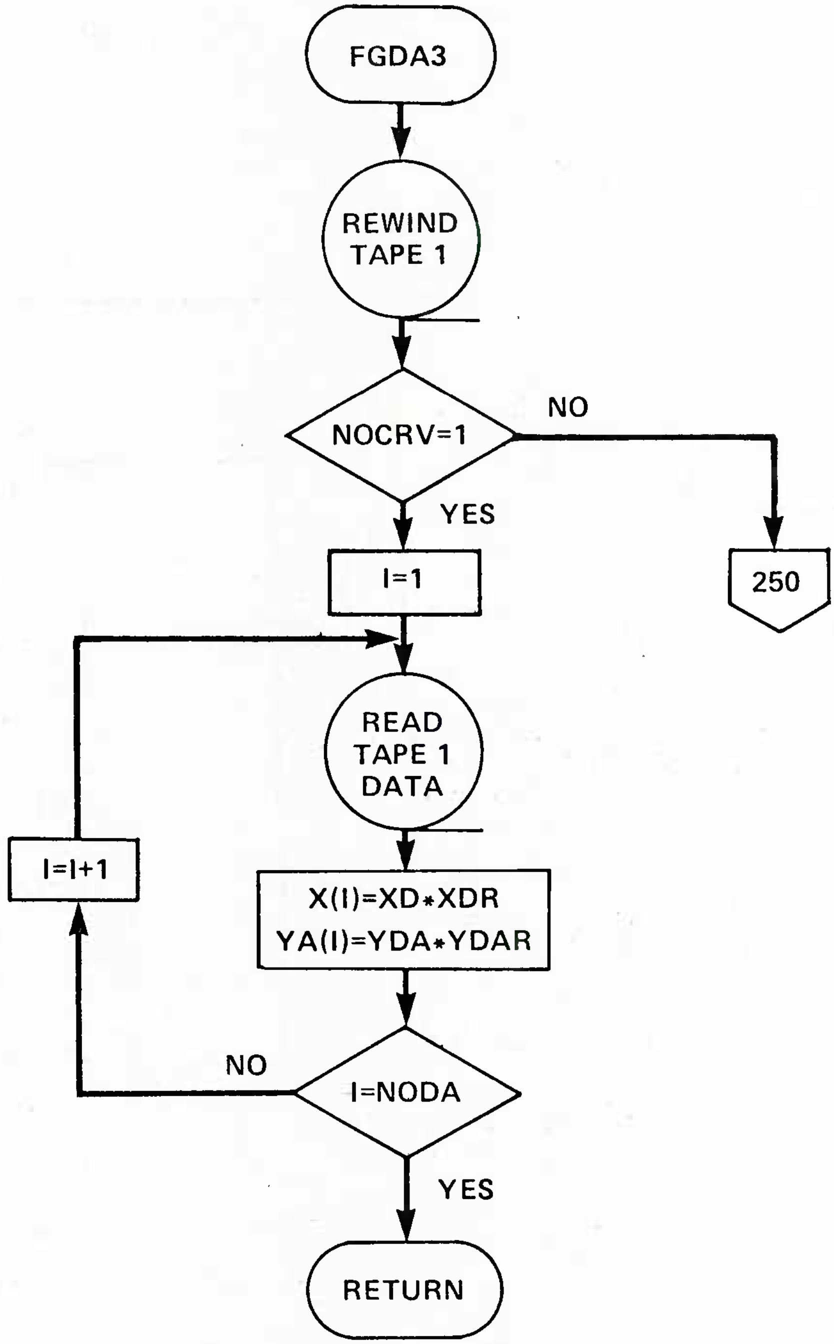


Figure 13 (Continued)



Flowchart of Subroutine FGDA3

Figure 14

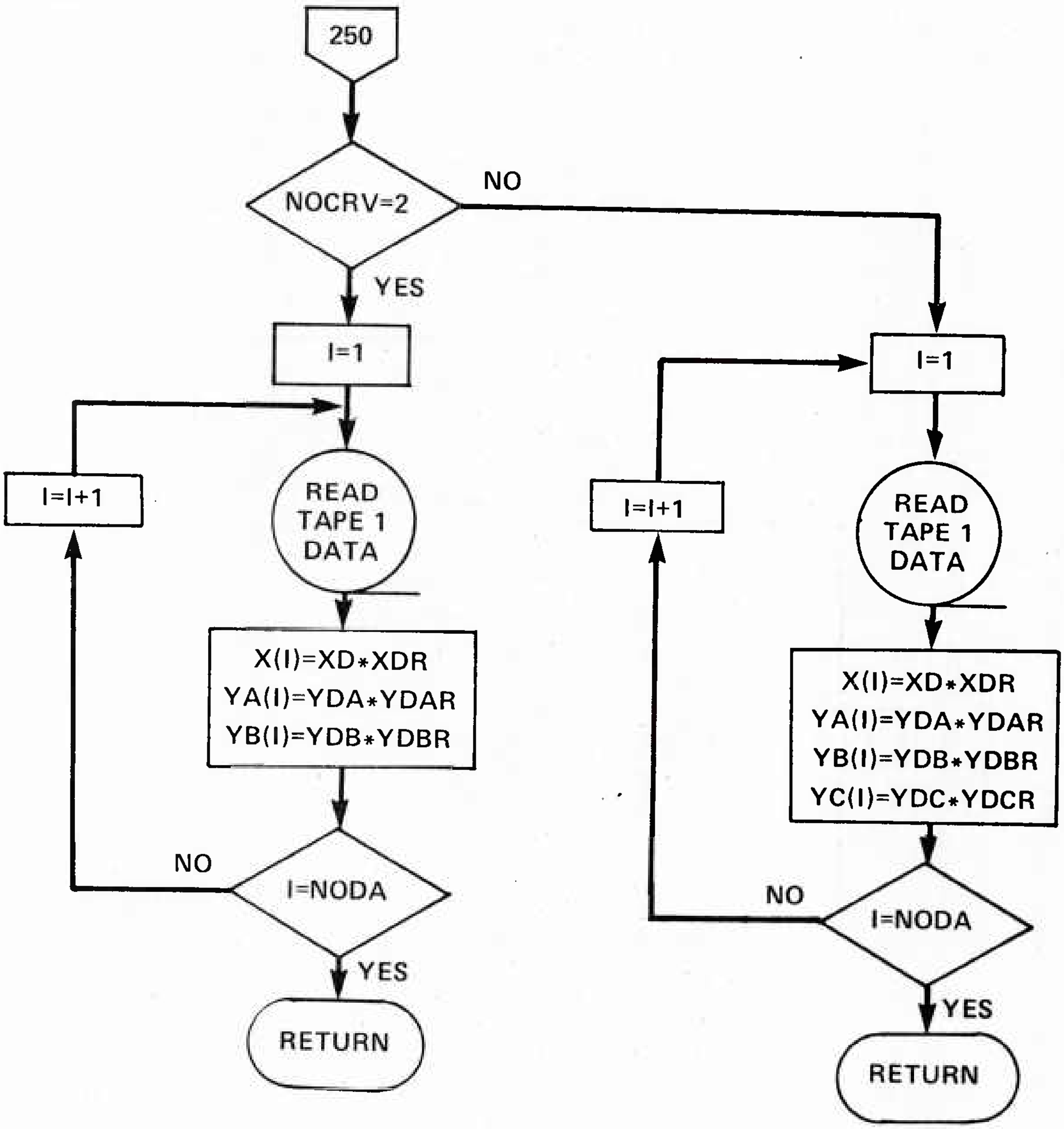
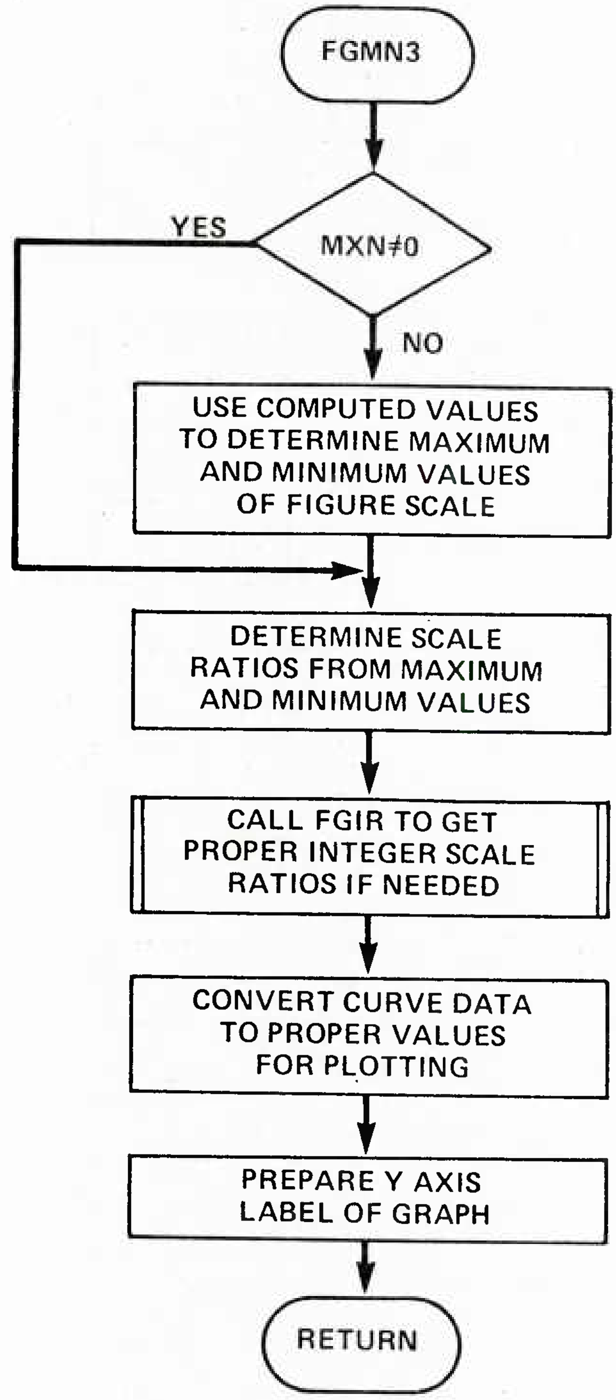
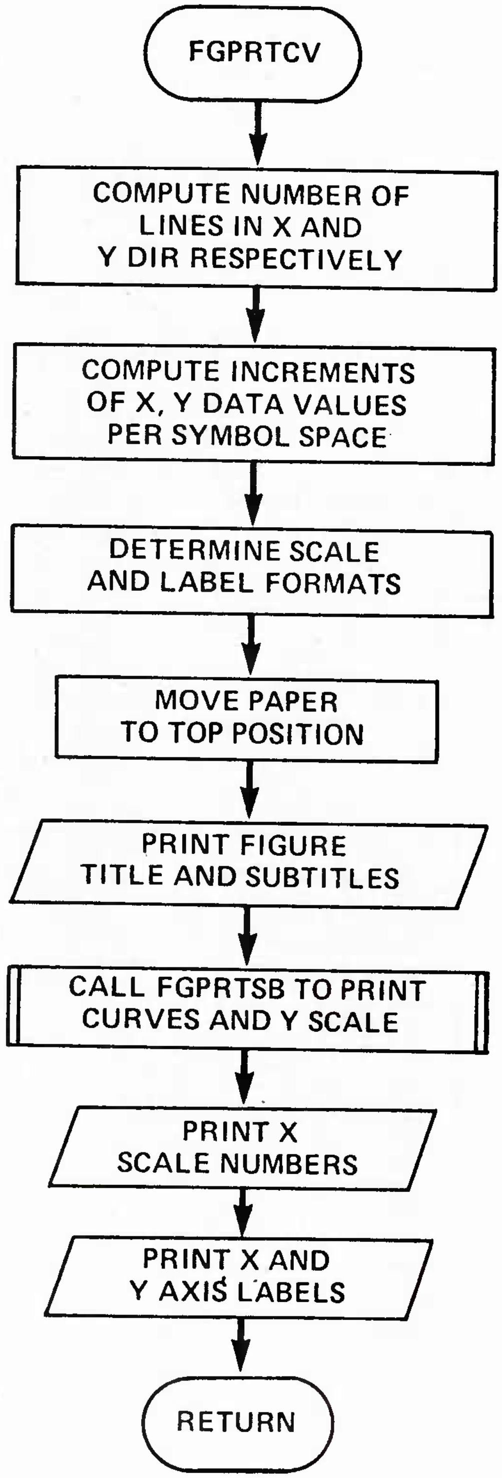


Figure 14 (Continued)



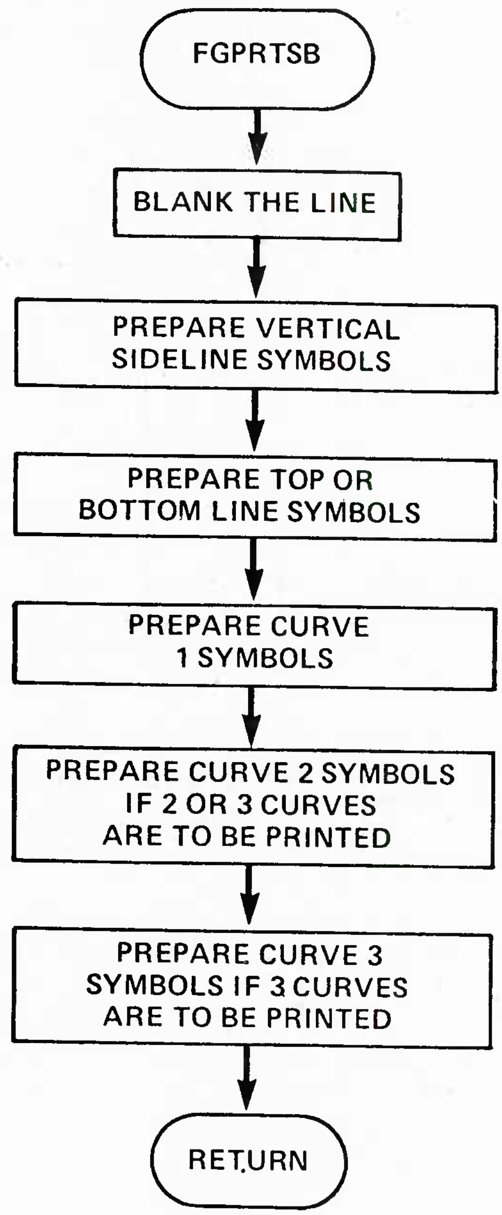
Flowchart of Subroutine FGMN3

Figure 15



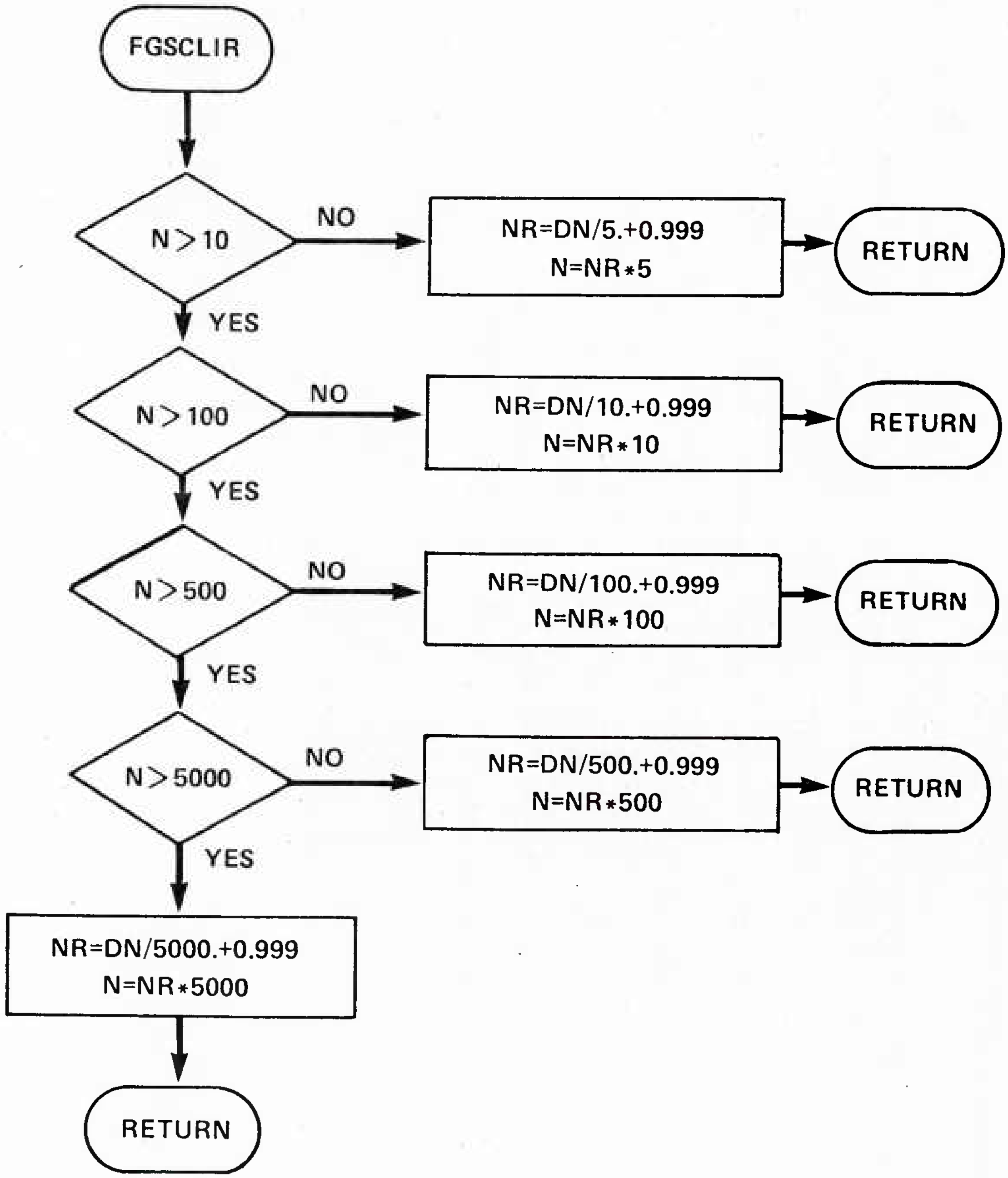
Flowchart of Subroutine FGPRTCV

Figure 16



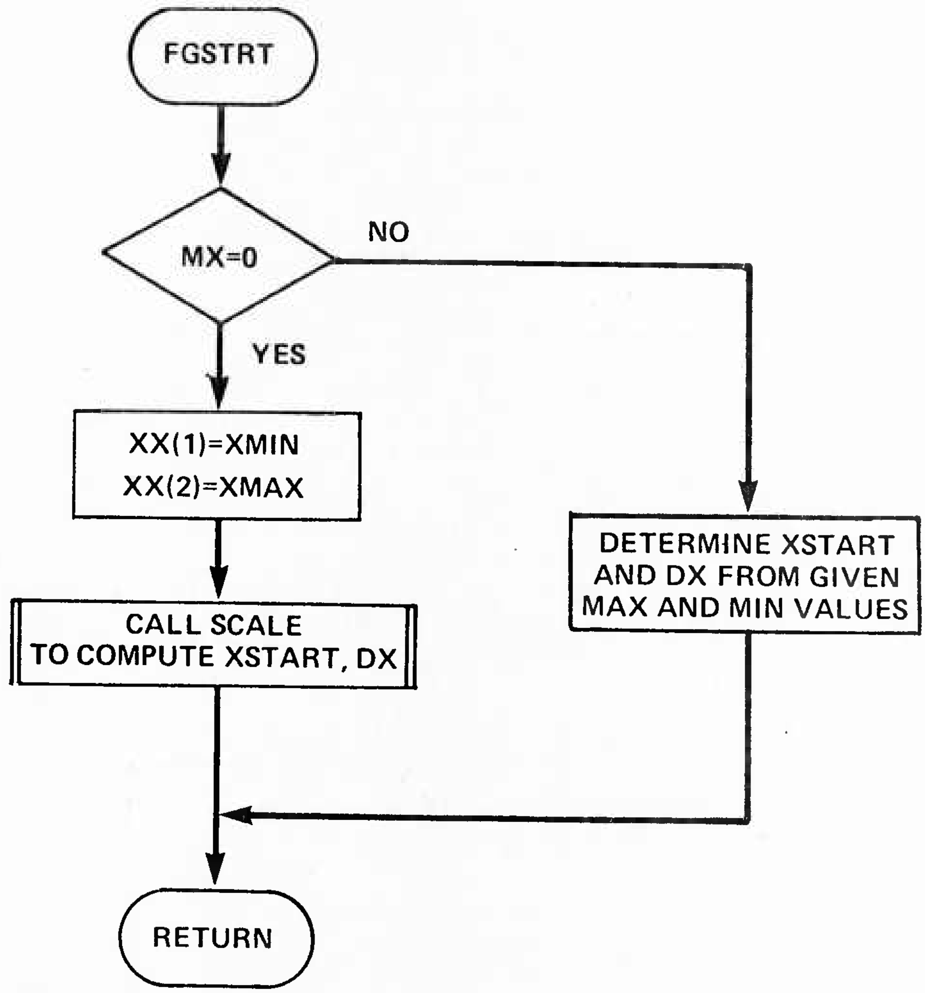
Flowchart of Subroutine FGPRTSB

Figure 17



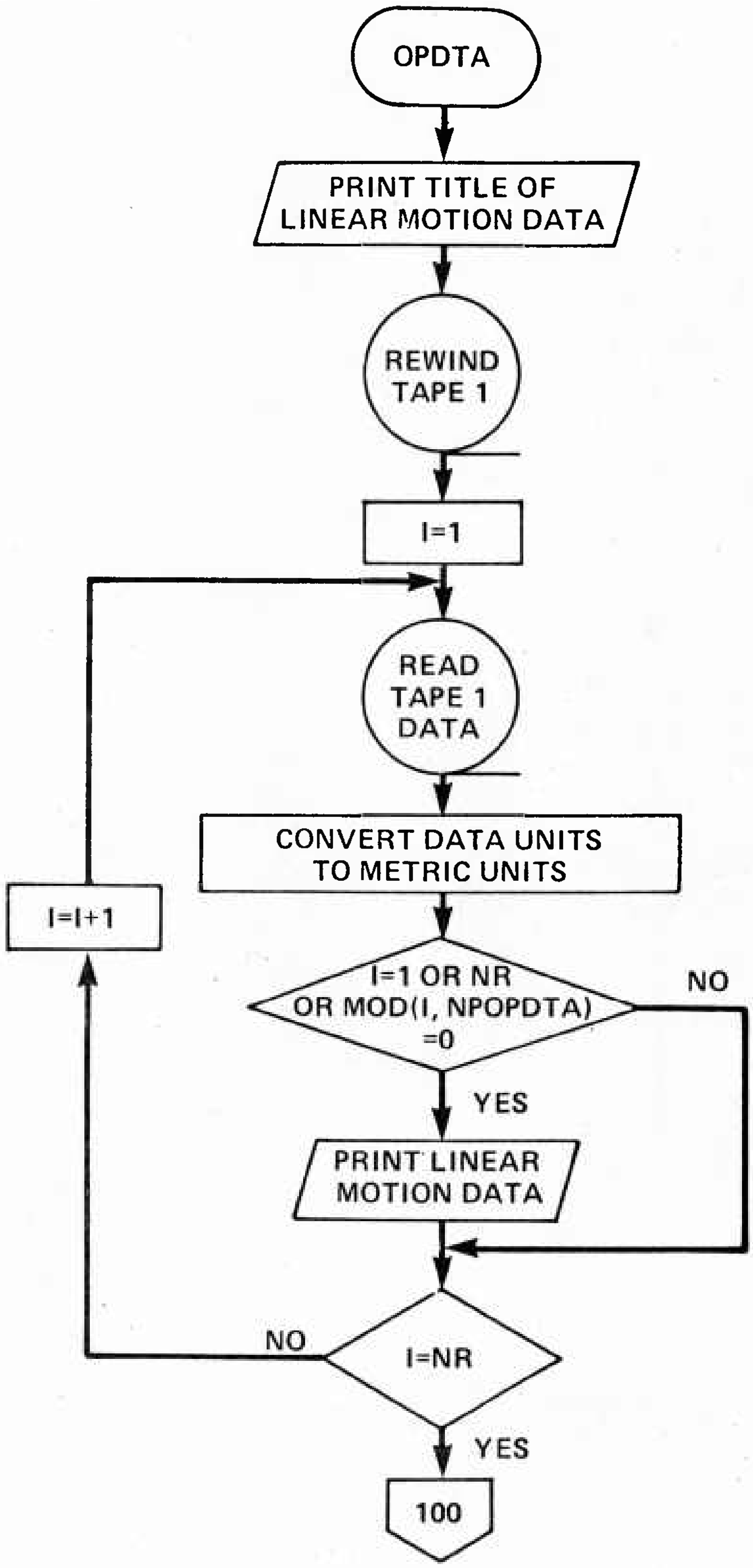
Flowchart of Subroutine FGSCLIR

Figure 18



Flowchart of Subroutine FGSTRT

Figure 19



Flowchart of Subroutine OPDTA

Figure 20

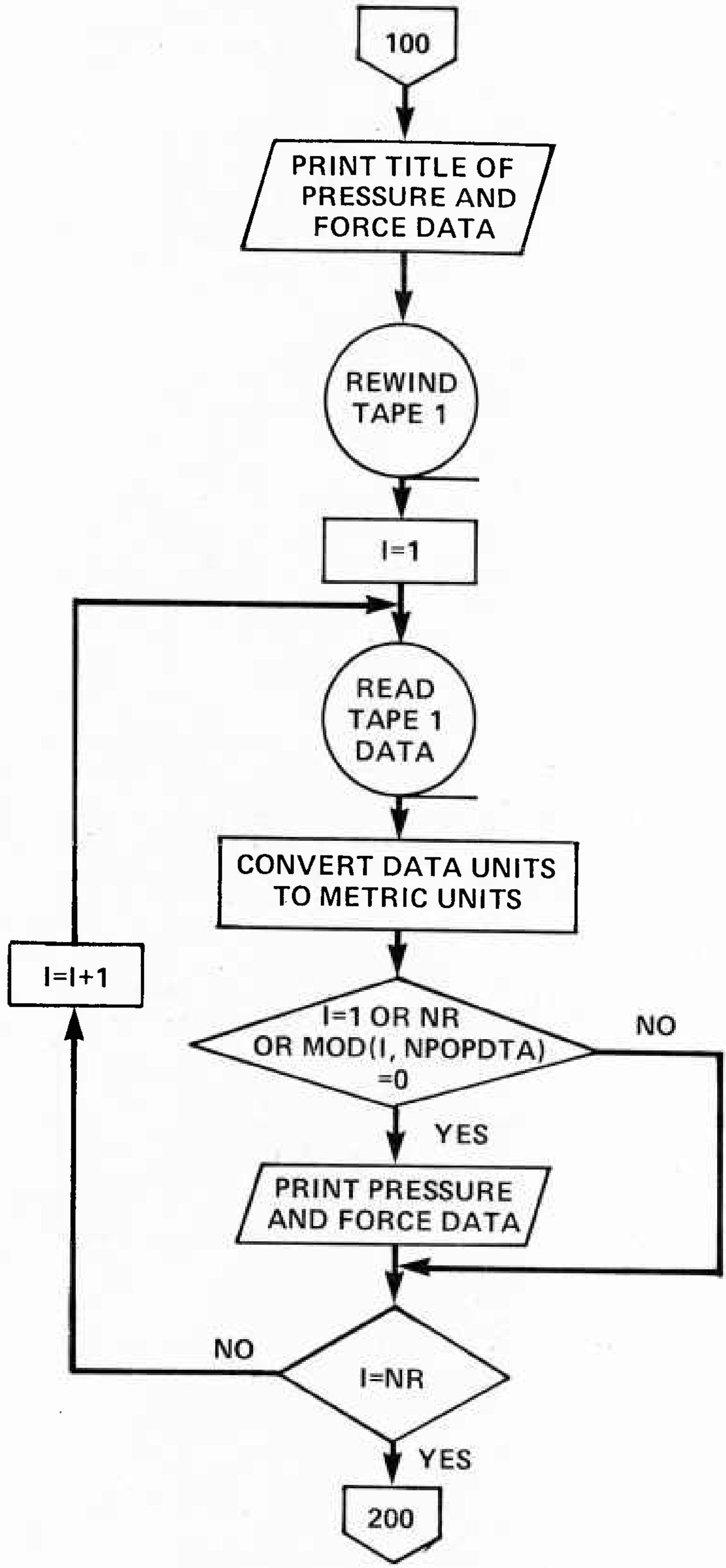
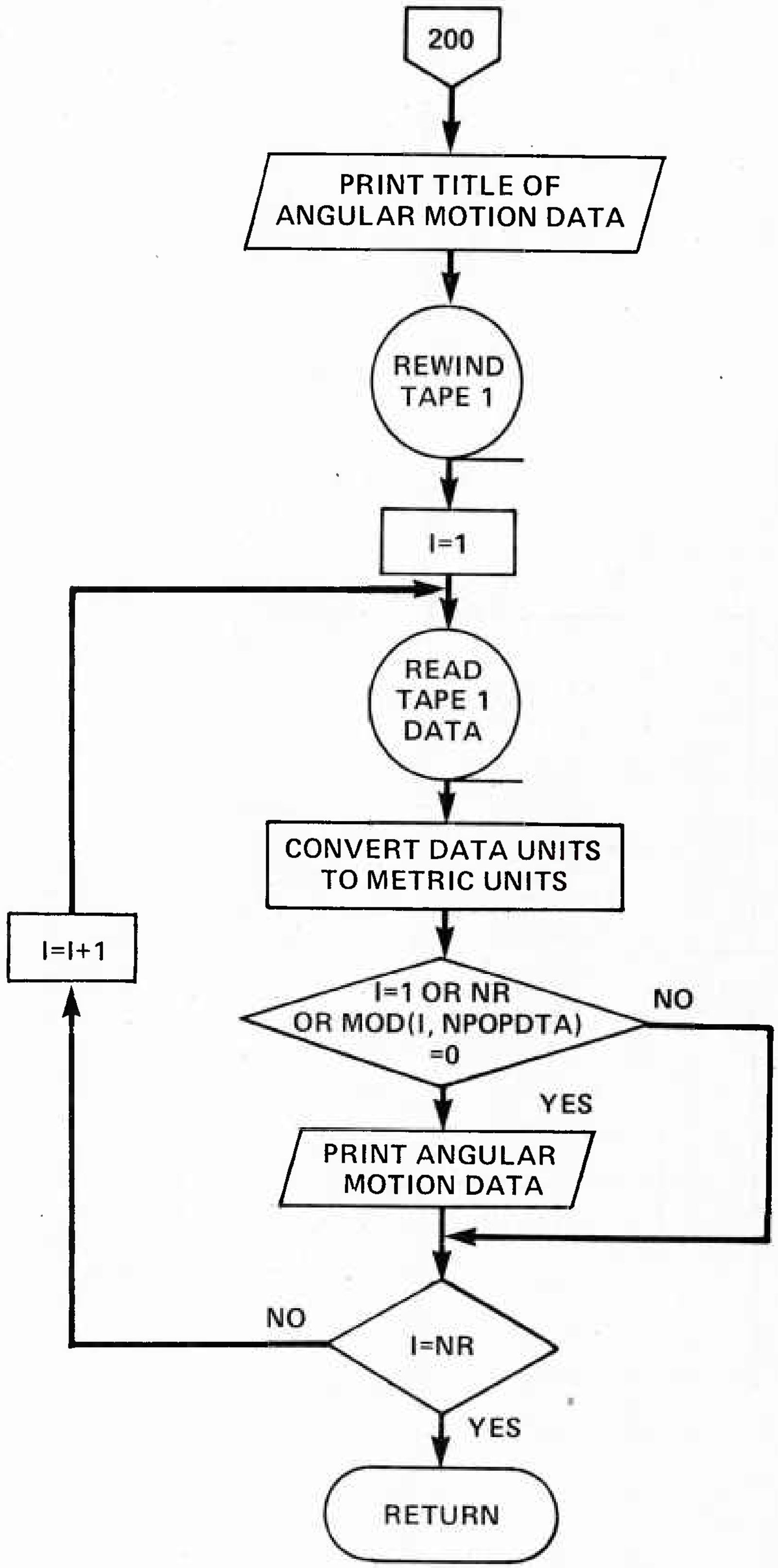


Figure 20 (Continued)



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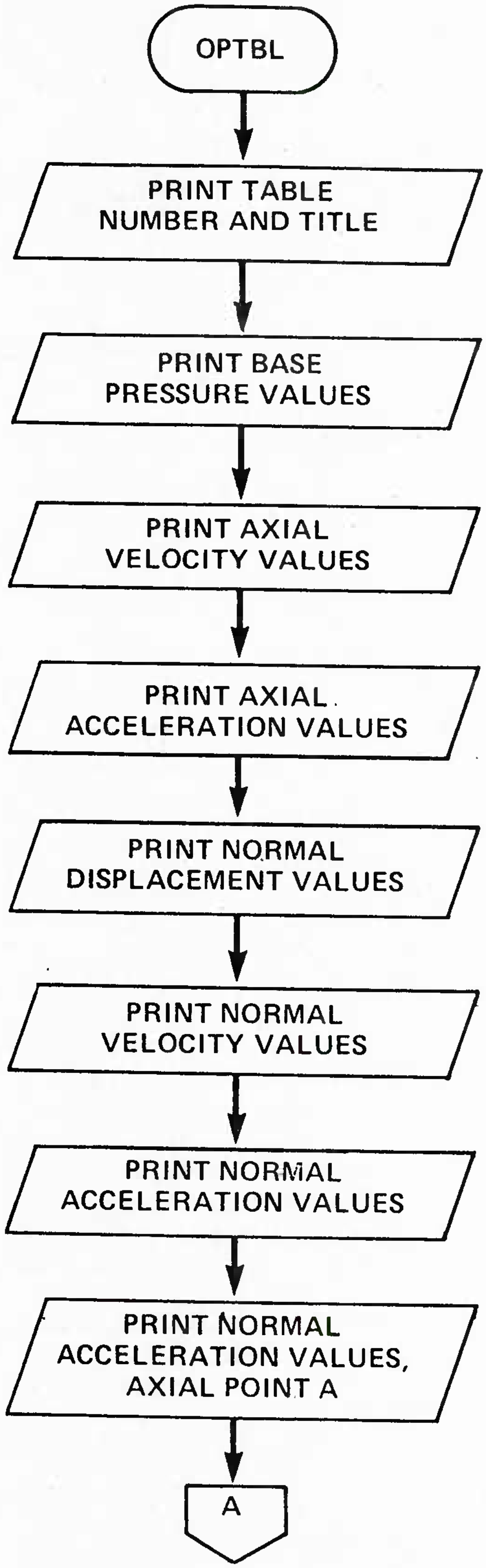
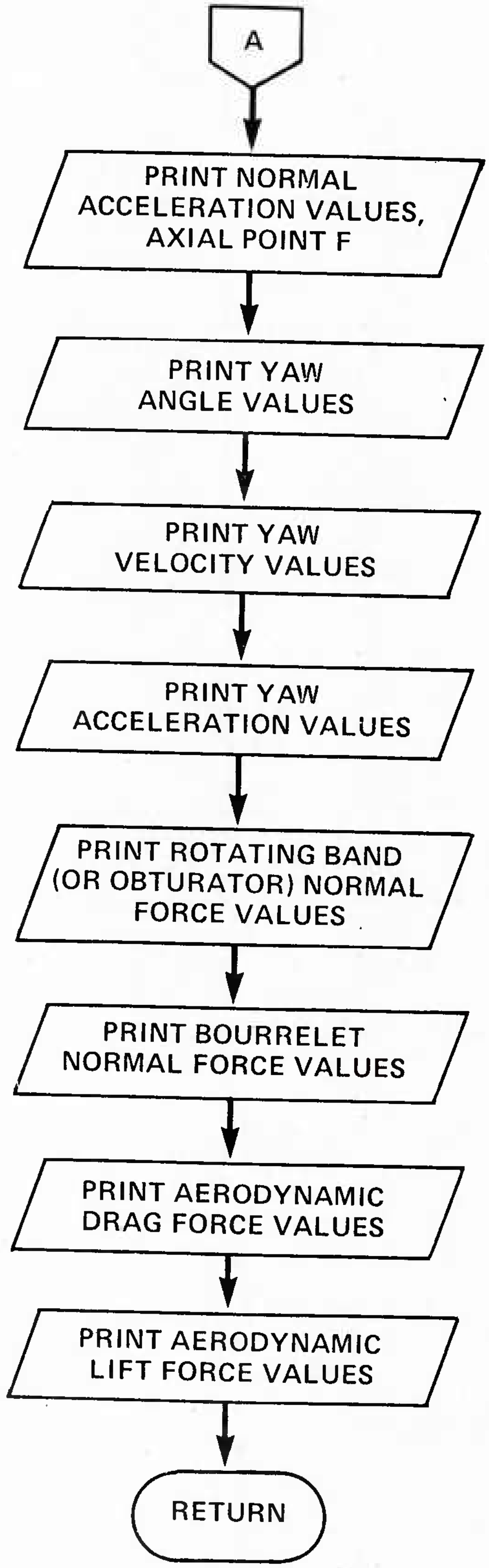


Flowchart of Subroutine OPTBL

Figure 21



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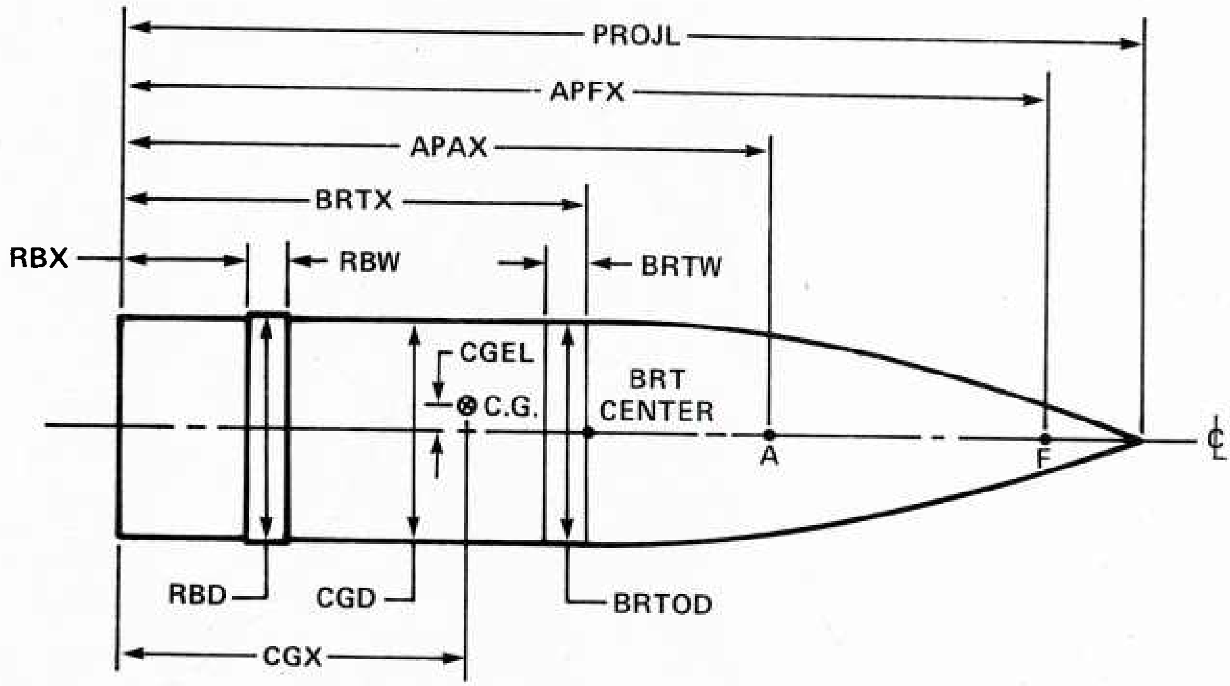
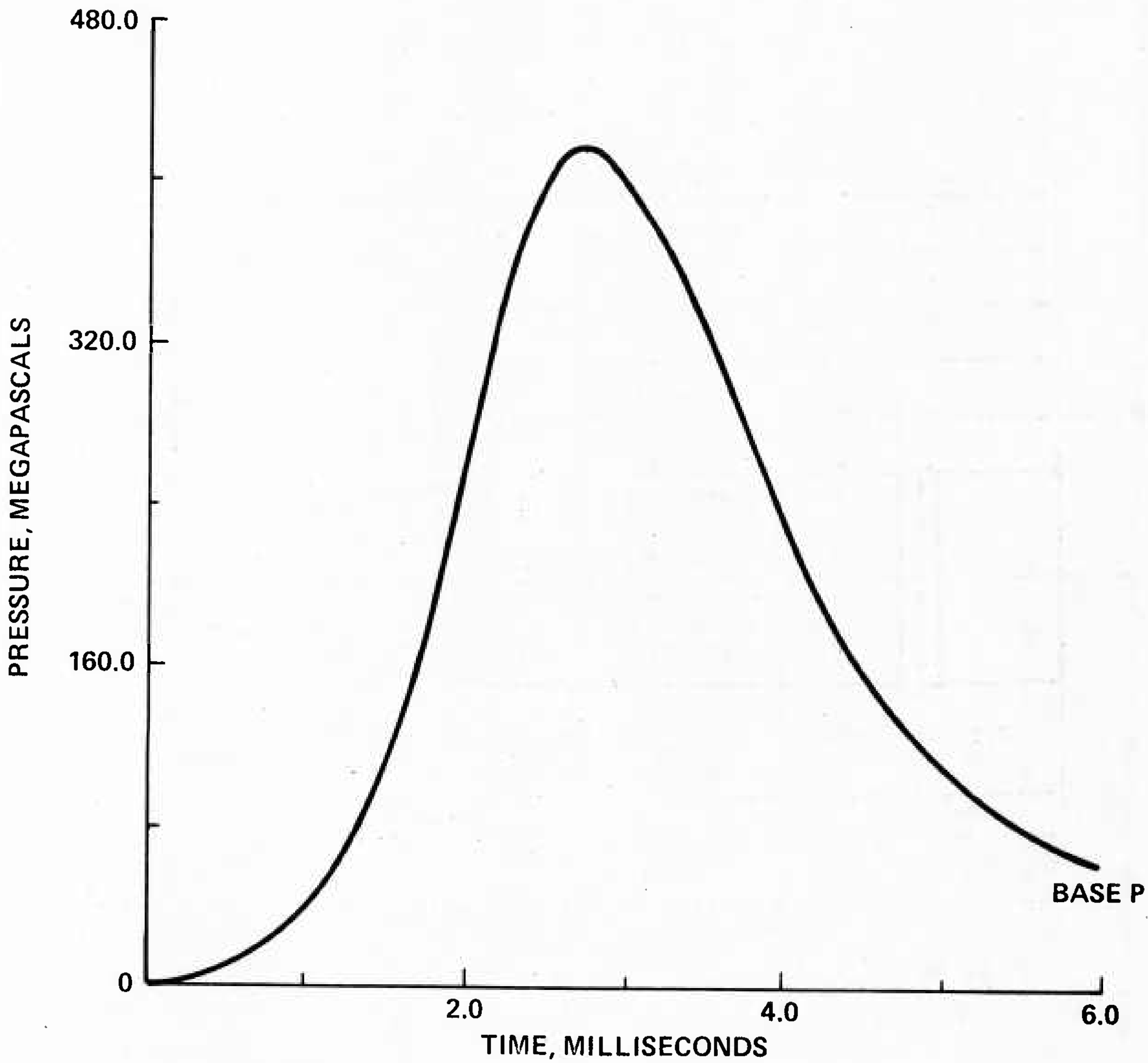


Projectile Input Dimensions

Figure 22



Base Pressure

Figure 23

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1. Chu, S. H. and Soechting, F. K., "Transverse Motion of an Accelerating Shell," Technical Report 4314, Picatinny Arsenal, Dover, NJ, June 1972.

2. Chu, S. H., "Transverse Motion of 8-Inch Projectile, XM673, Inside XM201, M2A2 Gun Tube, MK-16 and MCLG Gun," Technical Memorandum 2103, Picatinny Arsenal, Dover, NJ, August 1973.

3. Chu, S. H., "Transverse Motion of Eight-Inch Projectile, XM753, in Gun Tube XM201," Technical Report 4918, Picatinny Arsenal, Dover, NJ, December 1975.

4. Chu, S. H., Balloting Motion of an Accelerating Shell, Proceedings of The Fuze/Munitions Environment Characterization Symposium II, U.S. Army Armament Command, Picatinny Arsenal, Dover, NJ, 7-9 October 1975, pp 648-670.

5. Chu, S. H., "In-Bore Motion Analysis of XM712 Projectile in the M198 Gun," Technical Report ARLCD-TR-80005, ARDC, Dover, NJ, November 1980.

6. Chu, S. H., "Mathematical Modelling of In-Bore Motion of a Projectile in a Stationary Smooth Gun Tube," Technical Report ARLCD-TR-83023, ARDC, Dover, NJ, June 1983.

7. Corner, J., <u>Theory of the Interior Ballistics of Guns</u>, John Wiley and Sons, Inc., New York, 1950.

8. <u>Mark's Standard Handbook for Mechanical Engineers</u>, McGraw-Hill Book Company, Eighth Edition, New York, 1978.

APPENDIX A

INPUT DATA DECK

The preparation of the input data cards has been described in section: Input Data Coding. To facilitate preparation of input data cards, and for easy reference, the input data deck is tabulated below.

Input data deck

Card (set) order	Data type	Format	List of sybmols
1	Title	5A10	TITLEM(I), I=1,5
2	Subtitle	5A10	TITLES(I), I=1,5
3	Computation, output control	7I10	NDAMS, NDARAD,NIDTBL, NCCK, NOPTBL,NOOPDTA, NPOPDTA
4	Time	3F10.5	TMAX, TSTEP, TSLAST
5	Projectile (A)	8F10.5	PROJL, RBX, RBW, RBD, CGX, CGD, CGEL, CGEMT
	(B)	7F10.5	BRTX, BRTW, BRTOD, BRTID, BRTTK, APAX, APFX
	(C)	2F10.4	PWT, TMOI
6	Gun tube	4F10.5	ALPHA, BORED, FPEA, TRAVEL
7	Projectile inclination	3F10.5	BETA, THETA, THETAR
8	Figure (A)	8I10	NCGDVAA, NCGDVAN, NLF, NAPFA, NAF, NYAWDV, NYAWA, NFGVSX
	Omit following (B) - (N) cards if no figures desired.		
	(B)	I10, 3F10.5	MXMN, FGXMAXM, FGTMAX, FGXMAX
	Omit following (C) - (G) cards if MXMN = 0.		
	(C)	5F10.4	FTMAX, FTMIN, FXMAX, FXMIN, UNITMS
	(D)	6F10.4	FCGADMX, FCGADMN, FCGAVMX, FCGAVMN, FCGAAMX, FCGAAMN
	(E)	6F10.4	FCGNDMX, FCGNDMN, FCGNVMX, FCGNVMN, FCGNAMX, FCGNAMN
	(F)	6F10.4	FLFMX, FLFMN, FAPFMX, FAPFMN, FAFMX, FAFMN

	(G)	6F10.4	FYAWDMX, FYAWDMN, FYAWVMX, FYAWVMN, FYAWAMX, FYAWAMN
	(H)	6I10	NT(I), I=1,6
	(I)	5A10	TITLE(J,1), J=1,5 If NT(1) = 0, omit this card.
	(J)	5A10	TITLE(J,2), J=1,5 If NT(2) = 0, omit this card.
	(K)	5A10	TITLE(J,3), J=1,5 If NT(3) = 0, omit this card.
	(L)	5A10	TITLE(J,4), J=1,5 If NT(4) = 0, omit this card.
	(M)	5A10	TITLE(J,5), J=1,5 If NT(5) = 0, omit this card.
	(N)	5A10	TITLE(J,6), J=1,5 If NT(6) = 0, omit this card.
9	Firing pressure (A)	2I10, 4F10.5	NOFP, NCHAMP, CWT, PCGX, UNITFP
	(B)	4(F10.5, F10.2)	FPT(I), FP(I), I=1, NOFP
10	Tube wear (A)	I10, F10.5	NOTW, UNITTW
	(B)	8F10.5	TWMX(I), TWDC(I), I=1, NOTW If NOTW = 0, omit this card(s).
11	Bourrelet elasticity (A)	I10, 3F10.4	NOEBK, BRTK, BRTE, UNITBK
	(B)	4(F10.5, F10.2)	BDEF(I), BLOAD(I), I=1, NOEBK If NOEBK = 0, omit this card(s).
12	Band elasticity (A)	2I10, 4F10.4	NOERBK, NOERBMK, RBK, RBMK, RTBAND, UNITRBK
	(B)	4(F10.5, F10.2)	RBDEF(I), RBLOAD(I), I=1, NOERBK If NOERBK = 0, omit this card(s).
	(C)	4(F10.5, F10.2)	RBANG(I), RBM(I), I=1, NOERBMK If NOERBMK = 0, omit this card (s).
13	Friction (A)	I10, F10.2, 6F10.5	NORBPR, RBPRAV, RBMU, BRTMU, RBPW, RBPRMR, RBNU, UNITRBP

		(B)	4F10.5	RBOD, RBID, RBE, PROJRBD If RBPRAV is not zero or RBNU = 0, omit this card.
		(C)	4(F10.5, F10.2)	RBPMX(I), RBPR(I), I=1, NORBPR If RBPRAV is not zero or NORBPR = 0, omit this card(s).
14	Air resistance	(A)	I10, 5F10.5	NOCD, CDAV, RHO, AC, DTALAM, UNITAF
		(B)	8F10.5	CDANG(I), CD(I), I=1, NOCD If NOCD = 0, omit this card(s).
		(C)	2I10, 3F10.5	NOCL, NOCM, CLAV, CMAV, CHORD If DTALAM = 0, omit this and the following (D) and (E) cards.
		(D)	8F10.5	CLANG(I), CL(I), I=1, NOCL If NOCL = 0, omit this card(s).
		(E)	8F10.5	CMANG(I), CM(I), I=1, NOCM If NOCM = 0, omit this card(s).
15	End of data			7/8/9 in column 1

APPENDIX B

COMPUTER OUTPUT OF EXAMPLE OF COMPUTATION OF PROGRAM BALLOT2

Printer output, pages 123 - 149

Plotter output, pages 150 - 163

```
BALLOT2INBOREPROJECTILEMOTIONANALYSISPROGRAMBYSHCHUASDLCWSLARRADCOMDOVERNJVERSIONONE
BBBBBBBBBBBBAAAAAAAAAAAALLLLLLLLLLLLLLLLLLLLLLLLOOOOOOOOOOOOTTTTTTTTTTTT222222222222
BBBBBBBBBBBBAAAAAAAAAAAALLLLLLLLLLLLLLLLLLLLLLLLOOOOOOOOOOOOTTTTTTTTTTTT222222222222
BB       BBBAAAAAA AAAAALL  LLLLLLLLLL  LLLLLLLLOOO      OOOTT        TT222      222
BB  BBBB  BBAAAA    AAAALL  LLLLLLLLLL  LLLLLLLLOO  OOOO  OOTTTTT  TTTTT22  2222  22
BB  BBBB  BBAAA  AA  AAALL  LLLLLLLLLL  LLLLLLLLOO  OOOO  OOTTTTT  TTTTT2222222   22
BB       BBBAA  AAAA  AALL  LLLLLLLLLL  LLLLLLLLOO  OOOO  OOTTTTT  TTTTT2222      22
BB  BBBB  BBAA  AAAA  AALL  LLLLLLLLLL  LLLLLLLLOO  OOOO  OOTTTTT  TTTTT222      222
BB  BBBB  BBAA        AALL  LLLLLLLLLL  LLLLLLLLOO  OOOO  OOTTTTT  TTTTT22   2222222
BB  BBBB  BBAA  AAAA  AALL  LLLLLLLLLL  LLLLLLLLOO  OOOO  OOTTTTT  TTTTT22  22222222
BB  BBBB  BBAA  AAAA  AALL  LLLLLLLLLL  LLLLLLLLOO  OOOO  OOTTTTT  TTTTT22  22222222
BB       BBBAA  AAAA  AALL        LLLL        LLOOO      OOOTTTTT  TTTTT222       22
BBBBBBBBBBBBAAAAAAAAAAAALLLLLLLLLLLLLLLLLLLLLLLLOOOOOOOOOOOOTTTTTTTTTTTT222222222222
BBBBBBBBBBBBAAAAAAAAAAAALLLLLLLLLLLLLLLLLLLLLLLLOOOOOOOOOOOOTTTTTTTTTTTT222222222222
BALLOT2INBOREPROJECTILEMOTIONANALYSISPROGRAMBYSHCHUASDLCWSLARRADCOMDOVERNJVERSIONONE
```

IN-BORE MOTION ANALYSIS

OF PROJECTILE IN STATIONARY SMOOTH GUN TUBE

EXAMPLE OF COMPUTATION OF PROGRAM BALLOT2

DATE--- 01/11/83

TABLE 1 *****IN-BORE MOTION ANALYSIS INPUT DATA CARDS*****

```
--------------------------------------------------------------------------------
12345678901234567890123456789012345678901234567890123456789012345678901234567890
--------------------------------------------------------------------------------

(TITLE)
    EXAMPLE OF COMPUTATION OF PROGRAM BALLOT2
(SUBTITLE)

(COMPUTATION AND OUTPUT CONTROLS)
         0         0         0         0         0         0        20
(TIME DATA)
   6.00000    .00050   0.00000
(PROJECTILE DATA)
  23.04900   8.56500    .81000   0.00000  11.28050   3.17600  -.01000   0.00000
  13.60500    .62500   4.71500   0.00000   0.00000   5.00000   2.50000
   15.5977    7.2095
(GUN TUBE DATA)
   0.00000   4.73400   0.00000 187.00000
(PROJECTILE INCLINATION)
   0.00000 0.0000000   1.00000
(OUTPUT FIGURE DATA)
         1         1         1         1         1         1         1         1
         0   4.80000   6.00000   0.00000
(OUTPUT FIGURE SUBTITLE CONTROLS AND SUBTITLES)
         0         0         0         0         0         0
(TIME-PRESSURE DATA)
        63         0    .25000   0.00000   0.00000
   0.00000    100.00    .10000    264.00    .20000    443.00    .30000    676.00
    .40000    979.00    .50000   1371.00    .60000   1877.00    .70000   2515.00
    .80000   3335.00    .90000   4370.00   1.00000   5670.00   1.10000   7288.00
   1.20000   9283.00   1.30000  11669.00   1.41600  14746.00   1.41605  14697.00
   1.50000  17267.00   1.60000  20754.00   1.70000  24770.00   1.80000  29379.00
   1.90000  34293.00   2.00000  39285.00   2.10000  44302.00   2.20000  48974.00
   2.30000  53053.00   2.40000  56337.00   2.50000  58704.00   2.60000  60118.00
   2.70000  60630.00   2.80000  60348.00   2.90000  59416.00   3.00000  57973.00
   3.10000  56209.00   3.20000  54160.00   3.30000  51975.00   3.40000  49731.00
   3.50000  47487.00   3.60000  45284.00   3.70000  42650.00   3.80000  39651.00
   3.90000  36687.00   4.00000  33869.00   4.10000  31248.00   4.20000  28839.00
   4.30000  26656.00   4.40000  24688.00   4.50000  22913.00   4.60000  21310.00
   4.70000  19861.00   4.80000  18549.00   4.90000  17357.00   5.00000  16274.00
   5.10000  15287.00   5.10500  15322.00   5.20000  14402.00   5.30000  13565.00
   5.40000  12802.00   5.50000  12104.00   5.60000  11463.00   5.70000  10874.00
   5.80000  10331.00   5.90000   9828.00   5.94500   9614.00
(TUBE WEAR DATA)
         0   0.00000
(BOURRELET ELASTICITY DATA)
         0    .28000   0.00000   0.00000
(BAND ELASTICITY DATA)
         0         0    .83000   0.00000   0.00000   0.00000
(FRICTION DATA)
         0   5125.00    .04000    .15000   0.00000   0.00000   0.00000   0.00000
(AERODYNAMIC COEFFICIENT DATA)
         0   1.00000   0.00000   0.00000   0.00000   0.00000
(END)
```

TABLE 2 PROJECTILE AND GUN TUBE DATA

EXAMPLE OF COMPUTATION OF PROGRAM BALLOT2

DIMENSIONS AND PROPERTIES OF PROJECTILE

LENGTH OF PROJECTILE	(23.049 IN)	58.544 CM
OBTURATOR TO BASE DISTANCE	(8.565 IN)	21.755 CM
OBTURATOR WIDTH	(.810 IN)	2.057 CM
C. G. TO BASE DISTANCE	(11.281 IN)	28.652 CM
C. G. ECCENTRICITY (DISTANCE)	(-.0100 IN)	-.254 MM
C. G. ECCENTRICITY (MOMENT)	(-2.5 IN-OZ)	-17.62 MM-N
BOURRELET TO BASE DISTANCE	(13.605 IN)	34.557 CM
BOURRELET DIAMETER	(4.715 IN)	11.976 CM
BOURRELET SPRING CONSTANT (10E6)	(.28 LB/IN)	.4903 N/CM
OBTURATOR SPRING CONSTANT (10E6)	(.83 LB/IN)	1.4535 N/CM
AVERAGE OBTURATOR-TUBE PRESSURE	(5.1 KSI)	35.34 MPA
DRAG COEFFICIENT OF AIR RESISTANCE		1.0000
AXIAL POINT A TO NOSE DISTANCE	(5.000 IN)	12.700 CM
AXIAL POINT F TO NOSE DISTANCE	(2.500 IN)	6.350 CM
WEIGHT OF PROJECTILE	(15.598 LB)	7.075 KG
TRANSVERSE MOMENT OF INERTIA	(7.21 LB-INSQ)	2.110 G-MSQ
FRICTION COEFFICIENT AT BOURRELET		.1500
FRICTION COEFF. AT OBTURATOR OR DRIVING BAND		.0400
INITIAL SHELL ORIENTATION, BETA	(0.0 DEG)	0.000 RAD
THETA	(-.1175 DEG)	-2.0507 MRAD
INITIAL C. G. POSITION, X	(2.3105 IN)	5.869 CM
Y	(-.0147 IN)	-.037 CM
INITIAL COMPUTATION TIME INTERVAL		.00050 MS

DIMENSIONS AND PROPERTIES OF GUN TUBE

TUBE INCLINATION	(0.00 DEG)	0.000 RAD
BORE DIAMETER	(4.734 IN)	12.024 CM
TRAVEL OF PROJECTILE	(187.000 IN)	4.750 M

TABLE 3 BASE PRESSURE DATA

IN-BORE MOTION ANALYSIS
EXAMPLE OF COMPUTATION OF PROGRAM BALLOT2

CHARGE WEIGHT = .113 KGS OR .250 LBS

PRESSURE ACTING AREA = 113.5570 CM.SQ. OR 17.6014 IN.SQ.
PRESSURE CENTER TO C.G. DISTANCE = 5.8687 CM OR 2.3105 IN

TIME MILLISECONDS	FIRING PRESSURE MEGAPA(PSI)	TIME MILLISECONDS	FIRING PRESSURE MEGAPA(PSI)
0.0000	.69 (100.)	3.1000	387.55 (56209.)
.1000	1.82 (264.)	3.2000	373.42 (54160.)
.2000	3.05 (443.)	3.3000	358.36 (51975.)
.3000	4.66 (676.)	3.4000	342.88 (49731.)
.4000	6.75 (979.)	3.5000	327.41 (47487.)
.5000	9.45 (1371.)	3.6000	312.22 (45284.)
.6000	12.94 (1877.)	3.7000	294.06 (42650.)
.7000	17.34 (2515.)	3.8000	273.38 (39651.)
.8000	22.99 (3335.)	3.9000	252.95 (36687.)
.9000	30.13 (4370.)	4.0000	233.52 (33869.)
1.0000	39.09 (5670.)	4.1000	215.45 (31248.)
1.1000	50.25 (7288.)	4.2000	198.84 (28839.)
1.2000	64.00 (9283.)	4.3000	183.79 (26656.)
1.3000	80.45 (11669.)	4.4000	170.22 (24688.)
1.4160	101.67 (14746.)	4.5000	157.98 (22913.)
1.4161	101.33 (14697.)	4.6000	146.93 (21310.)
1.5000	119.05 (17267.)	4.7000	136.94 (19861.)
1.6000	143.09 (20754.)	4.8000	127.89 (18549.)
1.7000	170.78 (24770.)	4.9000	119.67 (17357.)
1.8000	202.56 (29379.)	5.0000	112.21 (16274.)
1.9000	236.44 (34293.)	5.1000	105.40 (15287.)
2.0000	270.86 (39285.)	5.1050	105.64 (15322.)
2.1000	305.45 (44302.)	5.2000	99.30 (14402.)
2.2000	337.66 (48974.)	5.3000	93.53 (13565.)
2.3000	365.79 (53053.)	5.4000	88.27 (12802.)
2.4000	388.43 (56337.)	5.5000	83.45 (12104.)
2.5000	404.75 (58704.)	5.6000	79.03 (11463.)
2.6000	414.50 (60118.)	5.7000	74.97 (10874.)
2.7000	418.03 (60630.)	5.8000	71.23 (10331.)
2.8000	416.08 (60348.)	5.9000	67.76 (9828.)
2.9000	409.66 (59416.)	5.9450	66.29 (9614.)
3.0000	399.71 (57973.)		

TABLE 4 OBTURATOR-TUBE PRESSURE DATA

IN-BORE MOTION ANALYSIS
EXAMPLE OF COMPUTATION OF PROGRAM BALLOT2

FRICTION COEFFICIENT USED IN FRICTION FORCE COMPUTATION,
AT OBTURATOR = .04000
AT BOURRELET = .15000

OBTURATOR-TUBE PRESSURE VS. MUZZLE DISTANCE

MUZZLE DISTANCE METERS (INCHES)	PRESSURE MEGAPA(KSI)	MUZZLE DISTANCE METERS (INCHES)	PRESSURE MEGAPA(KSI)
0.000 (0.00)	0.00 (0.00)	4.750 (187.00)	70.67 (10.25)

AVERAGE OBTURATOR-TUBE PRESSURE = 35.34 MEGAPA OR 5.13 KSI

TABLE 5

*****SOME PRELIMINARILY COMPUTED VALUES OR GIVEN DATA*****

```
GIVEN AND COMPUTED C.G. POSITION WITH RESPECT TO  ROTATING BAND OR OBTURATOR CENTER
  X =   5.86861 CM, OR     2.31047 IN.
  Y =   -.03743 CM, OR     -.01474 IN.

GIVEN INITIAL THETA =  -.0020507 RAD. OR -.1174961 DEG.
COMPUTED MIN. CONTACT ANGLE =  -.0020507 RAD, OR  -.1174961 DEG

C.G. ECCENTRICITY (DISTANCE TO PROJ. AXIS) =    -.02540 CM, OR    -.01000 IN.
C.G. ECCENTRICITY (UNBALANCED  MOMENT) =   -1.76222 CM-KG, OR   -2.49563 IN-OZ

INITIAL OR CONSTANT TIME STEP SIZE = .000500 MS
TIME STEP SIZE INCREMENT FOR EACH COMPUTATION =0.000000 MS

EVERY  20TH COMPUTED DATA ARE RECORDED IF WANTED
```

TABLE 6

*****INTERMEDIATE PRINTOUT OF COMPUTED VALUES OF MAIN QUANTITIES VS. TIME*****

(DATA IN ENGLISH UNITS ARE PRINTED OUT ON NEXT LINE WITH E12.5 FORMAT)

NC	TIME,MS	X,CM(IN)	THETA,MRD	Y,CM(IN)	YAW V,RPS	XDT,MPS(FPS)	XDDT,GEE	YDT,MPS(FPS)	YDDT,GEE	ON,N(LB)	YAW A,RPSS	BN,N(LB)
1	0.0000	0.000 0.	-2.051	-.037 -.14738E-01	0.000	0.00 0.	0.00	0.00 0.	0.00	0. 0.	0.	1.1E-08 .24869E-08
301	.1500	.000 .89383E-05	-2.050	-.037 -.14739E-01	.037	.02 .54536E-01	82.26	-.00 -.22869E-02	-1.82	0. 0.	5.65E+02	0. 0.
601	.3000	.002 .94453E-03	-2.053	-.037 -.14751E-01	-.168	.39 .12832E+01	446.13	-.00 -.11206E-01	-2.12	9.0E+00 .20311E+01	-2.22E+03	2.2E+01 .49319E+01
901	.4500	.015 .59455E-02	-2.093	-.038 -.14782E-01	-.225	1.44 .47172E+01	1008.81	-.01 -.24795E-01	-3.81	-1.8E+02 -.39855E+02	2.16E+03	1.7E+02 .39305E+02
1201	.6000	.050 .19865E-01	-2.112	-.038 -.14842E-01	-.187	3.47 .11398E+02	1800.76	-.01 -.41698E-01	-2.80	-1.2E+02 -.27496E+02	-2.88E+03	3.1E+02 .69151E+02
1501	.7500	.126 .49789E-01	-2.175	-.038 -.14930E-01	-.550	6.94 .22783E+02	2982.68	-.02 -.57253E-01	-4.32	-3.3E+02 -.74155E+02	3.16E+02	6.0E+02 .13430E+03
1801	.9000	.269 .10593E+00	-2.243	-.038 -.15054E-01	-.407	12.47 .40924E+02	4612.56	-.02 -.81200E-01	-4.90	-4.5E+02 -.10157E+03	-1.17E+03	9.5E+02 .21329E+03
2101	1.0500	.515 .20285E+00	-2.341	-.039 -.15223E-01	-.930	20.92 .68650E+02	6991.44	-.03 -.10713E+00	-6.89	-6.6E+02 -.14864E+03	-2.73E+03	1.4E+03 .32362E+03
2401	1.2000	.917 .36104E+00	-2.486	-.039 -.15453E-01	-.933	33.44 .10970E+03	10154.09	-.05 -.15222E+00	-11.22	-1.0E+03 -.23551E+03	1.59E+02	2.1E+03 .48220E+03
2701	1.3500	1.546 .60848E+00	-2.656	-.040 -.15779E-01	-1.468	51.38 .16850E+03	14341.44	-.07 -.21338E+00	-14.65	-1.3E+03 -.28944E+03	-4.78E+03	3.0E+03 .68384E+03
3001	1.5000	2.491 .98084E+00	-2.901	-.041 -.16235E-01	-1.655	75.90 .24902E+03	19159.22	-.09 -.29748E+00	-19.63	-1.7E+03 -.37940E+03	-4.18E+01	4.3E+03 .97023E+03
3301	1.6500	3.863 .15209E+01	-3.187	-.043 -.16860E-01	-2.344	108.50 .35598E+03	25356.88	-.12 -.39972E+00	-23.61	-1.8E+03 -.40658E+03	-7.20E+03	5.9E+03 .13302E+04
3601	1.8000	5.797 .22821E+01	-3.592	-.045 -.17697E-01	-2.891	151.14 .49585E+03	32813.09	-.16 -.53850E+00	-34.15	-2.2E+03 -.48721E+03	-9.62E+02	8.1E+03 .18268E+04
3901	1.9500	8.456 .33292E+01	-4.062	-.048 -.18826E-01	-3.571	205.55 .67436E+03	41174.94	-.22 -.72189E+00	-41.36	-2.0E+03 -.44763E+03	-7.83E+03	1.1E+04 .24472E+04
4201	2.1000	12.025 .47342E+01	-4.670	-.052 -.20317E-01	-4.380	272.34 .89351E+03	49644.62	-.29 -.94149E+00	-49.29	-1.7E+03 -.37150E+03	-2.69E+03	1.4E+04 .32582E+04

4501	2.2500	16.687	-5.365	-.056	-5.036	351.10	57207.66	-.36	-45.17	-5.1E+02	-6.77E+03	1.9E+04
		.65695E+01		-.22225E-01		.11519E+04		-.11747E+01		-.11552E+03		.42420E+04
4801	2.4000	22.608	-6.158	-.062	-5.204	439.87	63200.56	-.42	-32.98	9.2E+02	-9.96E+02	2.4E+04
		.89008E+01		-.24525E-01		.14431E+04		-.13733E+01		.20670E+03		.53989E+04
5101	2.5500	29.918	-6.998	-.069	-5.995	535.63	66651.54	-.44	2.57	3.2E+03	8.39E+02	3.0E+04
		.11779E+02		-.27087E-01		.17573E+04		-.14448E+01		.71218E+03		.66586E+04
5401	2.7000	38.694	-7.803	-.075	-4.524	634.90	68008.11	-.40	51.57	5.6E+03	7.83E+02	3.5E+04
		.15234E+02		-.29618E-01		.20830E+04		-.13279E+01		.12570E+04		.78881E+04
5701	2.8500	48.966	-8.424	-.080	-3.598	734.46	67146.43	-.28	112.30	7.9E+03	1.51E+04	3.9E+04
		.19278E+02		-.31688E-01		.24096E+04		-.92312E+00		.17753E+04		.88694E+04
6001	3.0000	60.717	-8.714	-.083	-.146	831.75	64979.08	-.08	165.83	9.5E+03	1.94E+04	4.2E+04
		.23904E+02		-.32787E-01		.27288E+04		-.25451E+00		.21276E+04		.93662E+04
6301	3.1500	73.899	-8.555	-.082	2.402	925.07	61826.45	.19	193.44	9.6E+03	2.48E+04	4.1E+04
		.29094E+02		-.32464E-01		.30350E+04		.63572E+00		.21683E+04		.91756E+04
6601	3.3000	88.443	-7.869	-.077	6.579	1013.36	58207.54	.47	180.89	8.3E+03	1.89E+04	3.6E+04
		.34820E+02		-.30488E-01		.33247E+04		.15491E+01		.18563E+04		.81826E+04
6901	3.4500	104.272	-6.741	-.069	8.379	1096.17	54420.47	.70	116.31	5.0E+03	1.49E+04	2.9E+04
		.41052E+02		-.26982E-01		.35963E+04		.22941E+01		.11268E+04		.64742E+04
7201	3.6000	121.301	-5.314	-.057	10.219	1173.43	50685.55	.80	12.58	6.9E+02	-1.36E+03	1.9E+04
		.47756E+02		-.22495E-01		.38498E+04		.26086E+01		.15589E+03		.42955E+04
7501	3.7500	139.445	-3.904	-.045	8.578	1244.64	46035.12	.73	-106.29	-4.0E+03	-4.56E+03	9.3E+03
		.54900E+02		-.17904E-01		.40835E+04		.23952E+01		-.90737E+03		.20957E+04
7801	3.9000	158.604	-2.693	-.036	6.809	1308.63	41010.20	.50	-201.39	-7.4E+03	-3.11E+04	1.2E+03
		.62442E+02		-.14213E-01		.42934E+04		.16292E+01		-.16595E+04		.27537E+03
8101	4.0500	178.668	-1.908	-.031	4.996	1365.45	36351.68	.19	-189.14	-8.2E+03	7.09E+02	0.
		.70342E+02		-.12190E-01		.44798E+04		.63352E+00		-.18398E+04		0.
8401	4.2000	199.535	-1.442	-.030	-.527	1415.76	32155.63	-.03	-131.14	-5.8E+03	-5.93E+04	0.
		.78557E+02		-.11765E-01		.46449E+04		-.11098E+00		-.12982E+04		0.
8701	4.3500	221.112	-1.938	-.032	-4.073	1460.35	28582.59	-.25	-158.58	-7.0E+03	1.06E+04	0.
		.87052E+02		-.12565E-01		.47912E+04		-.80487E+00		-.15832E+04		0.
9001	4.5000	243.321	-2.562	-.037	-5.576	1500.04	25470.63	-.46	-112.97	-4.6E+03	-2.19E+04	1.4E+03
		.95796E+02		-.14679E-01		.49214E+04		-.15102E+01		-.10256E+04		.31128E+03
9301	4.6500	266.092	-3.430	-.045	-4.960	1535.51	22837.14	-.53	19.15	-7.4E+02	1.54E+04	7.7E+03
		.10476E+03		-.17713E-01		.50378E+04		-.17551E+01		-.16747E+03		.17236E+04
9601	4.8000	289.368	-4.087	-.052	-4.358	1567.36	20530.91	-.40	161.42	4.1E+03	-6.71E+02	1.3E+04
		.11392E+03		-.20569E-01		.51423E+04		-.13014E+01		.91678E+03		.29501E+04
9901	4.9500	313.097	-4.564	-.056	-.739	1596.08	18573.48	-.10	229.43	5.6E+03	4.36E+04	1.6E+04
		.12327E+03		-.22086E-01		.52365E+04		-.33056E+00		.12580E+04		.36869E+04
10201	5.1000	337.237	-4.294	-.055	3.242	1622.10	16858.74	.25	233.23	6.3E+03	6.02E+03	1.5E+04
		.13277E+03		-.21648E-01		.53218E+04		.82162E+00		.14168E+04		.33924E+04
10501	5.2500	361.749	-3.700	-.049	5.447	1645.85	15408.53	.53	128.90	2.6E+03	3.03E+04	1.0E+04

		.14242E+03		-.19275E-01		.53998E+04		.17295E+01		.59190E+03		.23456E+04
10801	5.4000	386.602	-2.630	-.040	7.512	1667.53	14101.60	.62	-9.45	-9.7E+02	-1.61E+04	3.0E+03
		.15221E+03		-.15802E-01		.54709E+04		.20187E+01		-.21829E+03		.67997E+03
11101	5.5500	411.766	-1.639	-.032	7.969	1687.42	12966.50	.51	-96.32	-5.1E+03	5.36E+04	0.
		.16211E+03		-.12402E-01		.55361E+04		.16891E+01		-.11460E+04	0.	
11401	5.7000	437.217	-.044	-.025	10.254	1705.72	11953.00	.42	-22.64	-1.5E+03	-5.35E+04	0.
		.17213E+03		-.97092E-02		.55962E+04		.13681E+01		-.32825E+03	0.	
11701	5.8500	462.931	.798	-.019	2.678	1722.64	11066.80	.39	-37.13	-3.1E+03	6.91E+03	0.
		.18226E+03		-.73029E-02		.56517E+04		.12908E+01		-.70472E+03	0.	
11841	5.9200	475.016	1.059	-.016	5.445	1730.10	10680.20	.36	-57.92	-4.8E+03	6.10E+04	0.
		.18701E+03		-.62627E-02		.56762E+04		.11777E+01		-.10688E+04	0.	

TOTAL NO OF COMPUTATION = 11841

TOTAL NO OF DATA RECORDED ON TAPE = 593

TABLE 9

*****DETAILED OUTPUT OF COMPUTATION*****

BASE PRESSURE, NORMAL AND FRICTIONAL FORCES AND AIR RESISTANCE

BP = BASE PRESSURE, KPA (.145 PSI)
BN = BOURRELET NORMAL FORCE, N (LB)
FD = AERODYNAMIC DRAG FORCE, N (LB)
FL = AERODYNAMIC LIFT FORCE, N (LB)
ON = BAND OR OBTURATOR NORMAL FORCE, N (LB)
FO1 = BAND OR OBTURATOR FRICTIONAL FORCE FROM BAND-TUBE PR., N (LB)
FO2 = BAND OR OBTURATOR FRICTIONAL FORCE FROM ON, N (LB)
FB = BOURRELET FRICTIONAL FORCE, N (LB)
FX, FY = X, Y TOTAL FORCE AT C.G., N (LB)

1 N = .22482 LB

NO	TIME,MS	BP,KPA	ON,N	BN,N	FL,N	FD,N	FO1,N	FO2,N	FB,N	FX,N	FY,N
1	0.0000	6.895E+02	0.	1.106E-08	0.	0.	-2.1969E+04	0.	-1.6593E-09	0.	0.
21	.2000	3.054E+03	1.7310E+01	0.	0.	-4.571E-05	-2.1969E+04	-6.924E-01	0.	1.271E+04	-1.2309E+02
41	.4000	6.750E+03	-1.1011E+02	1.193E+02	0.	-6.861E-03	-2.1969E+04	-4.405E+00	-1.7901E+01	5.466E+04	-2.1949E+02
61	.6000	1.294E+04	-1.2230E+02	3.076E+02	0.	-8.356E-02	-2.1967E+04	-4.892E+00	-4.6138E+01	1.249E+05	-1.9451E+02
81	.8000	2.299E+04	-4.1860E+02	7.187E+02	0.	-5.032E-01	-2.1961E+04	-1.674E+01	-1.0781E+02	2.390E+05	-3.4395E+02
101	1.0000	3.909E+04	-5.2775E+02	1.241E+03	0.	-2.177E+00	-2.1950E+04	-2.111E+01	-1.8621E+02	4.218E+05	-3.7591E+02
121	1.2000	6.400E+04	-1.0475E+03	2.145E+03	0.	-7.756E+00	-2.1927E+04	-4.190E+01	-3.2173E+02	7.045E+05	-7.7851E+02
141	1.4000	9.874E+04	-1.4545E+03	3.436E+03	0.	-2.398E+01	-2.1885E+04	-5.818E+01	-5.1546E+02	1.099E+06	-1.1527E+03
161	1.6000	1.431E+05	-1.7334E+03	5.320E+03	0.	-6.481E+01	-2.1814E+04	-6.934E+01	-7.9799E+02	1.602E+06	-1.4831E+03
181	1.8000	2.026E+05	-2.1671E+03	8.126E+03	0.	-1.586E+02	-2.1701E+04	-8.668E+01	-1.2189E+03	2.277E+06	-2.3692E+03
201	2.0000	2.709E+05	-1.9148E+03	1.199E+04	0.	-3.561E+02	-2.1529E+04	-7.659E+01	-1.7987E+03	3.052E+06	-3.0584E+03
221	2.2000	3.377E+05	-9.6670E+02	1.732E+04	0.	-7.275E+02	-2.1276E+04	-3.867E+01	-2.5977E+03	3.810E+06	-3.3476E+03
241	2.4000	3.884E+05	9.1942E+02	2.401E+04	0.	-1.344E+03	-2.0924E+04	-3.678E+01	-3.6021E+03	4.385E+06	-2.2878E+03
261	2.6000	4.145E+05	3.8245E+03	3.154E+04	0.	-2.246E+03	-2.0459E+04	-1.530E+02	-4.7311E+03	4.679E+06	9.8349E+02
281	2.8000	4.161E+05	7.3305E+03	3.814E+04	0.	-3.420E+03	-1.9872E+04	-2.932E+02	-5.7207E+03	4.695E+06	6.5236E+03
301	3.0000	3.997E+05	9.4635E+03	4.166E+04	0.	-4.810E+03	-1.9163E+04	-3.785E+02	-6.2491E+03	4.508E+06	1.1505E+04
321	3.2000	3.734E+05	9.2228E+03	3.978E+04	0.	-6.343E+03	-1.8336E+04	-3.689E+02	-5.9674E+03	4.209E+06	1.3308E+04
341	3.4000	3.429E+05	6.4082E+03	3.159E+04	0.	-7.950E+03	-1.7399E+04	-2.563E+02	-4.7386E+03	3.863E+06	1.0100E+04
361	3.6000	3.122E+05	6.9342E+02	1.911E+04	0.	-9.577E+03	-1.6361E+04	-2.774E+01	-2.8659E+03	3.516E+06	8.7289E+02
381	3.8000	2.734E+05	-5.5226E+03	6.377E+03	0.	-1.116E+04	-1.5232E+04	-2.209E+02	-9.5650E+02	3.077E+06	-1.0028E+04
401	4.0000	2.335E+05	-8.5068E+03	0.	0.	-1.263E+04	-1.4022E+04	-3.403E+02	0.	2.625E+06	-1.4291E+04
421	4.2000	1.988E+05	-5.7742E+03	0.	0.	-1.394E+04	-1.2743E+04	-2.310E+02	0.	2.231E+06	-9.0980E+03
441	4.4000	1.702E+05	-6.6089E+03	0.	0.	-1.512E+04	-1.1406E+04	-2.644E+02	0.	1.906E+06	-1.0789E+04
461	4.6000	1.469E+05	-2.3517E+03	5.578E+03	0.	-1.616E+04	-1.0019E+04	-9.407E+01	-8.3668E+02	1.641E+06	-2.1127E+03
481	4.8000	1.279E+05	4.0779E+03	1.312E+04	0.	-1.709E+04	-8.5887E+03	-1.631E+02	-1.9683E+03	1.424E+06	1.1199E+04
501	5.0000	1.122E+05	6.0484E+03	1.647E+04	0.	-1.792E+04	-7.1211E+03	-2.419E+02	-2.4698E+03	1.246E+06	1.6649E+04
521	5.2000	9.930E+04	4.1734E+03	1.232E+04	0.	-1.867E+04	-5.6208E+03	-1.669E+02	-1.8482E+03	1.101E+06	1.1982E+04
541	5.4000	8.827E+04	-9.7095E+02	3.024E+03	0.	-1.935E+04	-4.0916E+03	-3.884E+01	-4.5367E+02	9.783E+05	-6.5568E+02
561	5.6000	7.903E+04	-4.7130E+03	0.	0.	-1.996E+04	-2.5368E+03	-1.885E+02	0.	8.748E+05	-5.8395E+03
581	5.8000	7.123E+04	-1.4943E+03	0.	0.	-2.052E+04	-9.5903E+02	-5.977E+01	0.	7.873E+05	-1.0402E+03
593	5.9200	6.711E+04	-4.7539E+03	0.	0.	-2.083E+04	-2.3551E+00	-1.902E+02	0.	7.410E+05	-4.0181E+03

TABLE 10

*****DETAILED OUTPUT OF COMPUTATION*****
ANGULAR DISPLACEMENTS, VELOCITIES AND ACCELERATIONS AND MOMENTS

THETA = YAW ANGLE, MILLIRADIANS
THETAD = YAW VELOCITY, RAD/SEC
THTADD = YAW ACCELERATION, RAD/SEC/SEC
ZM = TOTAL MOMENT ABOUT C.G., N-M (IN-LB)
BM = MOMENT ABOUT C.G. FROM BOURRELET FORCES, N-M (IN-LB)
OM1 = MOMENT ABOUT C.G. FROM FORCE FO1, N-M (IN-LB)
OM2 = MOMENT ABOUT C.G. FROM OBTURATOR (BAND) FORCES, N-M (IN-LB)
OM3 = LATERAL ROTATION RESISTING MOMENT, N-M (IN-LB)
AM = MOMENT ABOUT C.G. FROM AIR RESISTANCE FORCE, N-M (IN-LB)

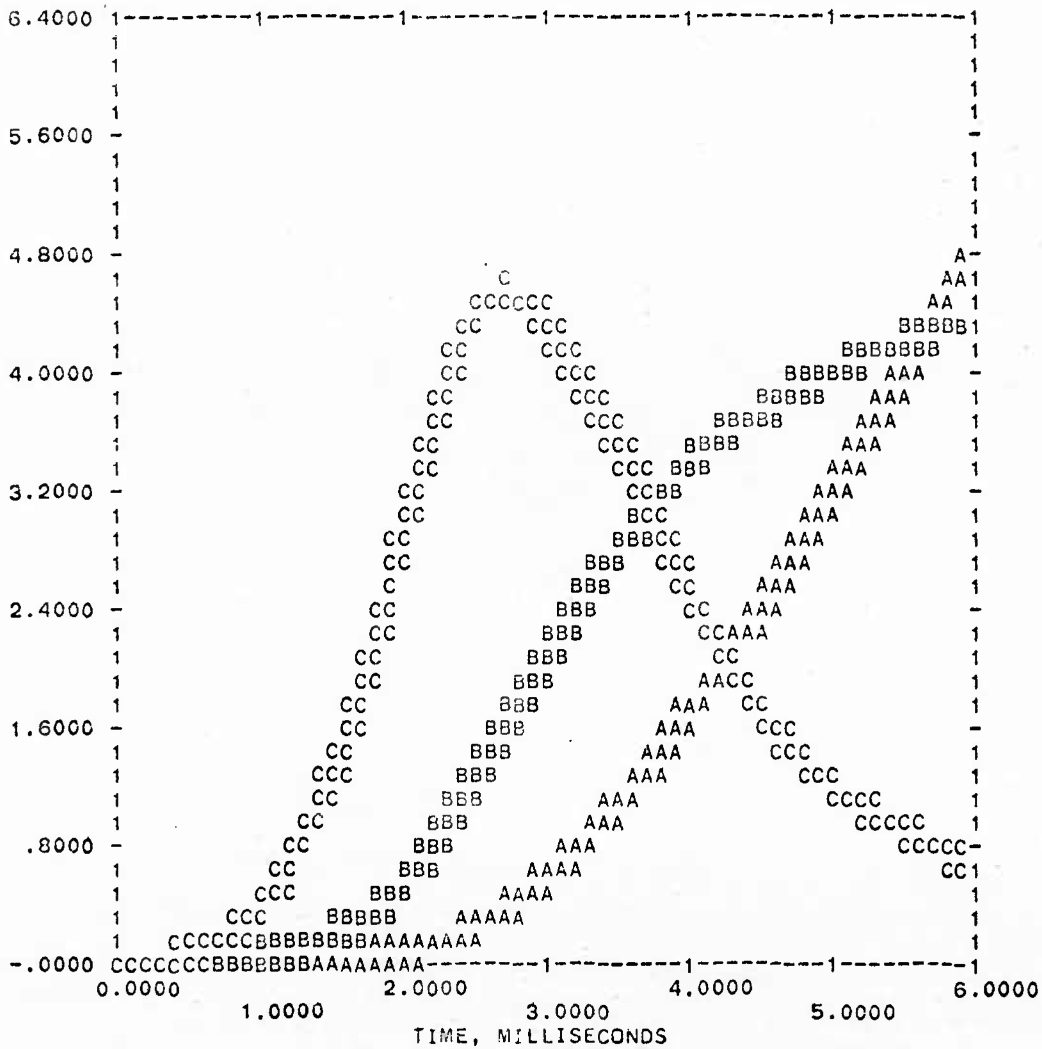
1 N-M = 8.850748 IN-LB

NO	TIME,MS	THETA,MRAD	THETAD,RPS	THTADD,RPSS	OM1,N-M	OM2,N-M	OM3,N-M	BM,N-M	AM,N-M	ZM,N-M
1	0.0000	-2.051E+00	0.	0.	8.2245E+00	0.	0.	5.526E-10	0.	0.
21	.2000	-2.048E+00	3.6283E-02	-7.827E+02	8.2260E+00	-1.059E+00	0.	0.	6.0839E-09	-1.652E+00
41	.4000	-2.079E+00	-3.0376E-01	7.190E+02	8.2412E+00	6.715E+00	0.	5.962E+00	9.0065E-07	1.517E+00
61	.6000	-2.112E+00	-1.8724E-01	-2.880E+03	8.2816E+00	7.458E+00	0.	1.537E+01	1.0803E-05	-6.078E+00
81	.8000	-2.201E+00	-4.8546E-01	2.011E+03	8.3490E+00	2.552E+01	0.	3.590E+01	6.2422E-05	4.243E+00
101	1.0000	-2.299E+00	-7.5119E-01	-4.000E+03	8.4529E+00	3.218E+01	0.	6.201E+01	2.5759E-04	-8.440E+00
121	1.2000	-2.486E+00	-9.3274E-01	1.588E+02	8.6061E+00	6.386E+01	0.	1.071E+02	8.3182E-04	3.351E-01
141	1.4000	-2.735E+00	-1.6457E+00	-2.033E+03	8.8464E+00	8.864E+01	0.	1.716E+02	2.2207E-03	-4.291E+00
161	1.6000	-3.078E+00	-1.9970E+00	-5.956E+03	9.2145E+00	1.056E+02	0.	2.655E+02	4.6864E-03	-1.257E+01
181	1.8000	-3.592E+00	-2.8907E+00	-9.621E+02	9.7534E+00	1.320E+02	0.	4.053E+02	6.6629E-03	-2.030E+00
201	2.0000	-4.250E+00	-3.9466E+00	-6.759E+03	1.0541E+01	1.165E+02	0.	5.977E+02	1.1343E-03	-1.426E+01
221	2.2000	-5.122E+00	-4.7150E+00	-5.939E+03	1.1639E+01	5.878E+01	0.	8.625E+02	-3.5117E-02	-1.253E+01
241	2.4000	-6.158E+00	-5.2040E+00	-9.962E+02	1.3031E+01	-5.649E+01	0.	1.195E+03	-1.4717E-01	-2.102E+00
261	2.6000	-7.293E+00	-5.7180E+00	9.270E+03	1.4521E+01	-2.352E+02	0.	1.568E+03	-3.9630E-01	1.956E+01
281	2.8000	-8.230E+00	-4.0782E+00	4.478E+03	1.5686E+01	-4.512E+02	0.	1.894E+03	-7.9282E-01	9.451E+00
301	3.0000	-8.714E+00	-1.4569E-01	1.943E+04	1.5958E+01	-5.828E+02	0.	2.068E+03	-1.2530E+00	4.100E+01
321	3.2000	-8.400E+00	3.8336E+00	3.112E+04	1.4902E+01	-5.678E+02	0.	1.975E+03	-1.5357E+00	6.568E+01
341	3.4000	-7.144E+00	7.7672E+00	9.880E+03	1.2512E+01	-3.941E+02	0.	1.570E+03	-1.3358E+00	2.085E+01
361	3.6000	-5.314E+00	1.0219E+01	-1.357E+03	9.3553E+00	-4.257E+01	0.	9.514E+02	-5.7507E-01	-2.864E+00
381	3.8000	-3.479E+00	8.4192E+00	-3.839E+03	6.3986E+00	3.363E+02	0.	3.181E+02	5.3966E-01	-8.101E+00
401	4.0000	-2.153E+00	4.7714E+00	3.248E+03	4.5127E+00	5.187E+02	0.	0.	1.6006E+00	6.854E+00
421	4.2000	-1.442E+00	-5.2699E-01	-5.932E+04	3.8079E+00	3.523E+02	0.	0.	2.3552E+00	-1.252E+02
441	4.4000	-2.128E+00	-3.6282E+00	2.810E+03	3.8007E+00	4.030E+02	0.	0.	1.9417E+00	5.931E+00
461	4.6000	-3.161E+00	-5.7695E+00	1.452E+04	4.2370E+00	1.433E+02	0.	2.783E+02	1.0912E+00	3.065E+01
481	4.8000	-4.087E+00	-4.3584E+00	-6.710E+02	4.4857E+00	-2.500E+02	0.	6.543E+02	2.1954E-01	-1.416E+00
501	5.0000	-4.548E+00	1.3123E+00	3.598E+04	4.0106E+00	-3.710E+02	0.	8.207E+02	-2.6092E-01	7.592E+01
521	5.2000	-3.938E+00	4.1433E+00	2.016E+04	2.8915E+00	-2.559E+02	0.	6.144E+02	3.9893E-01	4.255E+01
541	5.4000	-2.630E+00	7.5117E+00	-1.609E+04	1.6436E+00	5.918E+01	0.	1.510E+02	1.9056E+00	-3.395E+01
561	5.6000	-1.173E+00	1.0607E+01	4.419E+04	7.3737E-01	2.877E+02	0.	0.	3.6816E+00	9.326E+01
581	5.8000	6.490E-01	3.7189E+00	-4.718E+04	1.9731E-01	9.136E+01	0.	0.	5.9952E+00	-9.957E+01
593	5.9200	1.059E+00	5.4448E+00	6.101E+04	3.7507E-04	2.908E+02	0.	0.	6.5894E+00	1.288E+02

FIGURE 1 C.G. MOTION, AXIAL

EXAMPLE OF COMPUTATION OF PROGRAM BALLOT2

CG ECC=-.025MM,CG DIST=28.65CM, OBTR-BRT L=11.77CM
BORE DIAMETER = 12.024CM, BOURRELET D.= 11.976CM
FRICTION COEFF.= .040(OBTURATOR), .150(BOURRELET)
SPRING C.(MN/CM)=1.45(OBTURATOR), .49(BOURRELET)

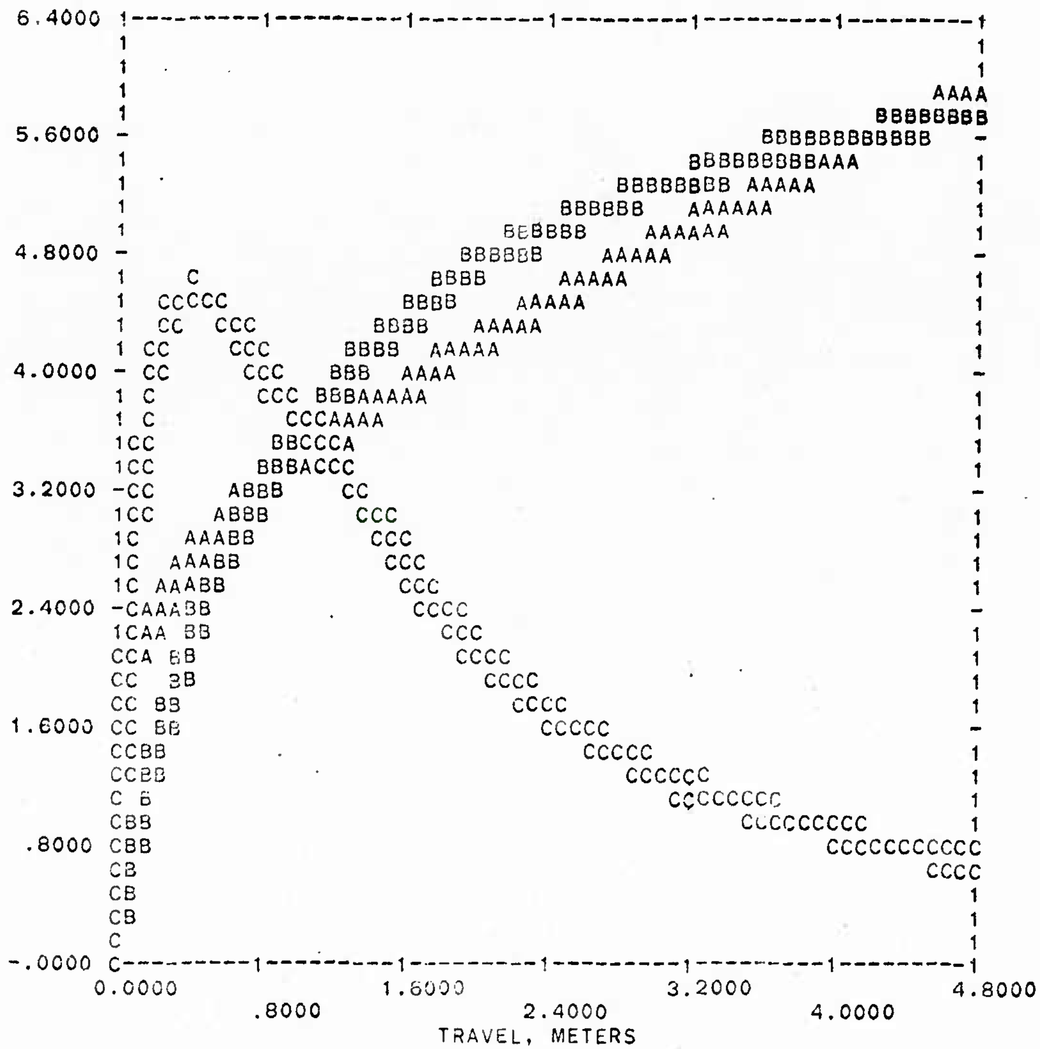


CURVE A = TRAVEL, B = VELOCITY, C = ACCELERATION
SCALE OF VERTICAL AXIS-----
TRAVEL,M. VELOCITY,X400 M/SEC ACCELERATION,X15000 GEE

FIGURE 2 C.G. MOTION, AXIAL

EXAMPLE OF COMPUTATION OF PROGRAM BALLOT2

CG ECC=-.025MM,CG DIST=28.65CM, OBTR-BRT L=11.77CM
BORE DIAMETER = 12.024CM, BOURRELET D.= 11.976CM
FRICTION COEFF.= .040(OBTURATOR), .150(BOURRELET)
SPRING C.(MN/CM)=1.45(OBTURATOR), .49(BOURRELET)

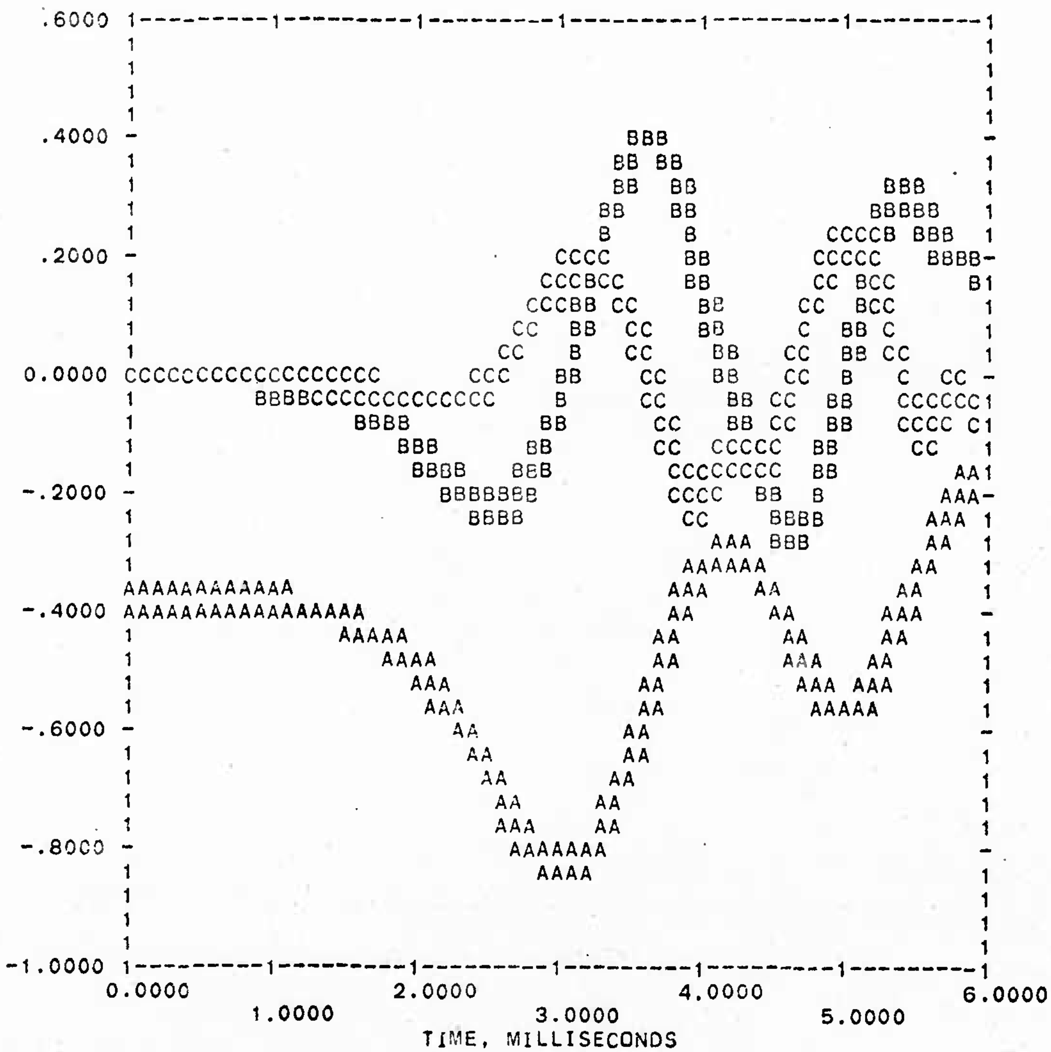


CURVE A = TIME, B = VELOCITY, C = ACCELERATION
SCALE OF VERTICAL AXIS-----
TIME,MS. VELOCITY,X300 M/SEC ACCELERATION,X15000 GEE

FIGURE 3 C.G. MOTION, NORMAL

EXAMPLE OF COMPUTATION OF PROGRAM BALLOT2

CG ECC=-.025MM,CG DIST=28.65CM, OBTR-BRT L=11.77CM
BORE DIAMETER = 12.024CM, BOURRELET D.= 11.976CM
FRICTION COEFF.= .040(OBTURATOR), .150(BOURRELET)
SPRING C.(MN/CM)=1.45(OBTURATOR), .49(BOURRELET)

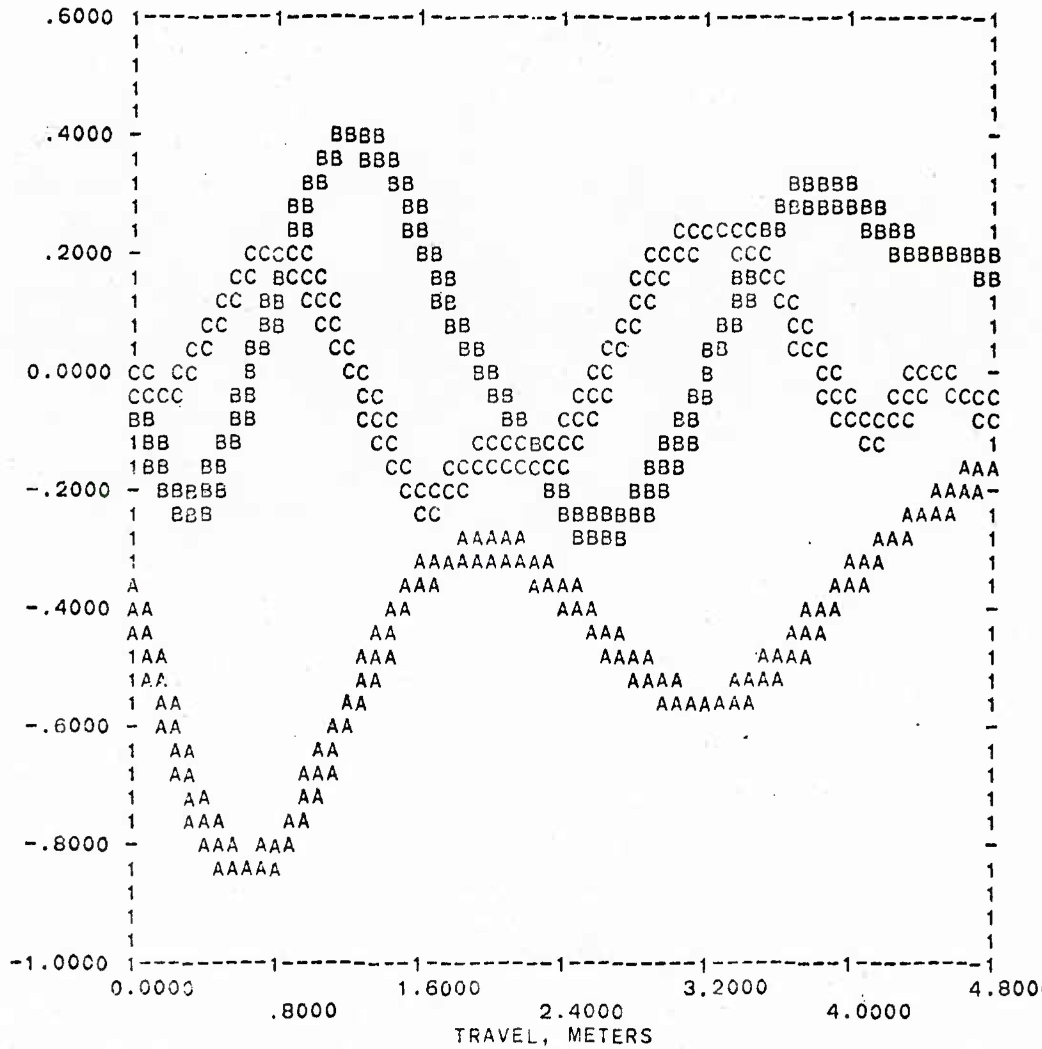


CURVE A = DISPLACEMENT, B = VELOCITY, C = ACCELERATION
SCALE OF VERTICAL AXIS-----
DISPL,MM. VELOCITY,X 2 M/SEC ACCELERATION,X 1000 GEE

FIGURE 4 C.G. MOTION, NORMAL

EXAMPLE OF COMPUTATION OF PROGRAM BALLOT2

CG ECC=-.025MM,CG DIST=28.65CM, OBTR-BRT L=11.77CM
BORE DIAMETER = 12.024CM, BOURRELET D.= 11.976CM
FRICTION COEFF.= .040(OBTURATOR), .150(BOURRELET)
SPRING C.(MN/CM)=1.45(OBTURATOR), .49(BOURRELET)

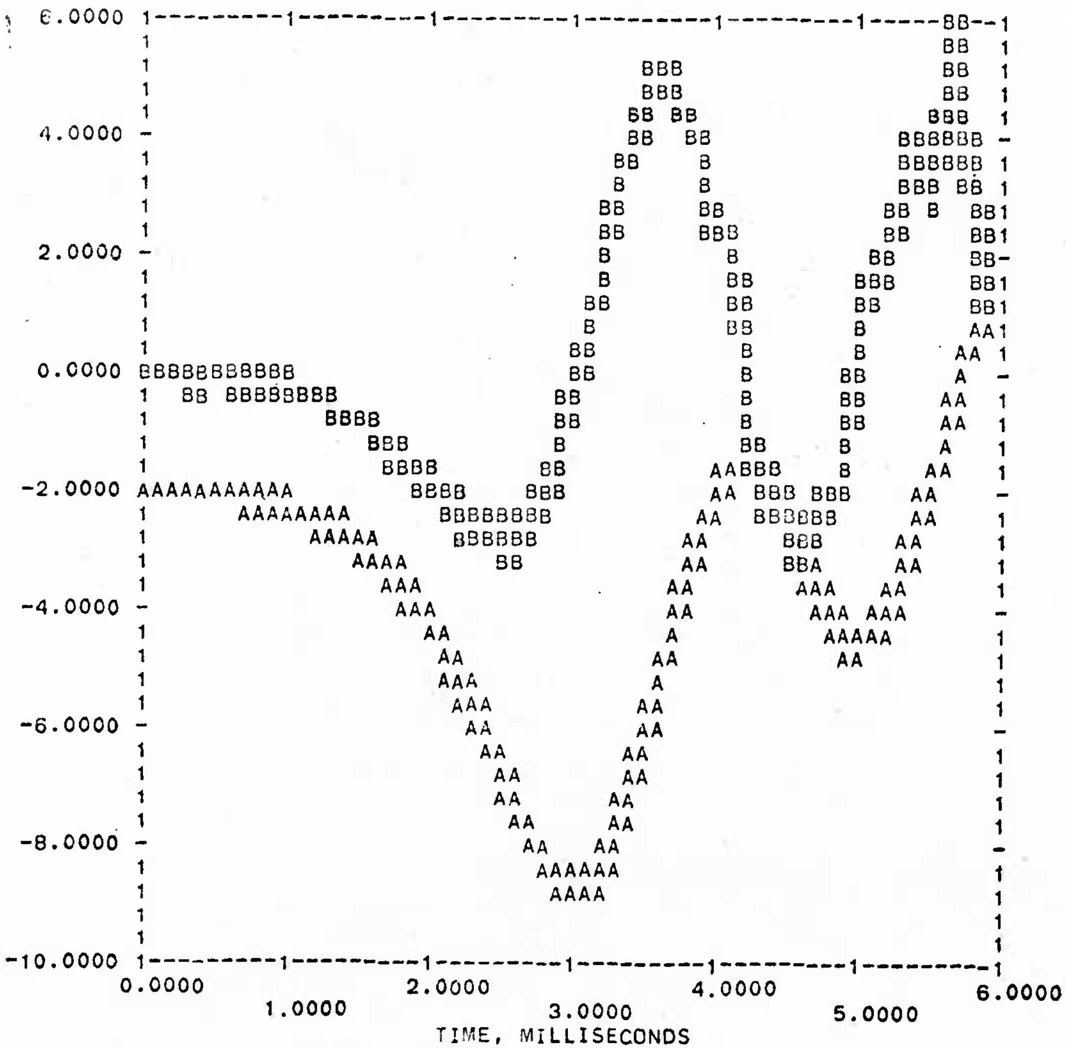


CURVE A = DISPLACEMENT, B = VELOCITY, C = ACCELERATION
SCALE OF VERTICAL AXIS-----
DISPL,MM. VELOCITY,X 2 M/SEC ACCELERATION,X 1000 GEE

FIGURE 5 YAW ANGLE AND VELOCITY

EXAMPLE OF COMPUTATION OF PROGRAM BALLOT2

CG ECC=-.025MM,CG DIST=28.65CM, OBTR-BRT L=11.77CM
BORE DIAMETER = 12.024CM, BOURRELET D.= 11.976CM
FRICTION COEFF.= .040(OBTURATOR), .150(BOURRELET)
SPRING C.(MN/CM)=1.45(OBTURATOR), .49(BOURRELET)

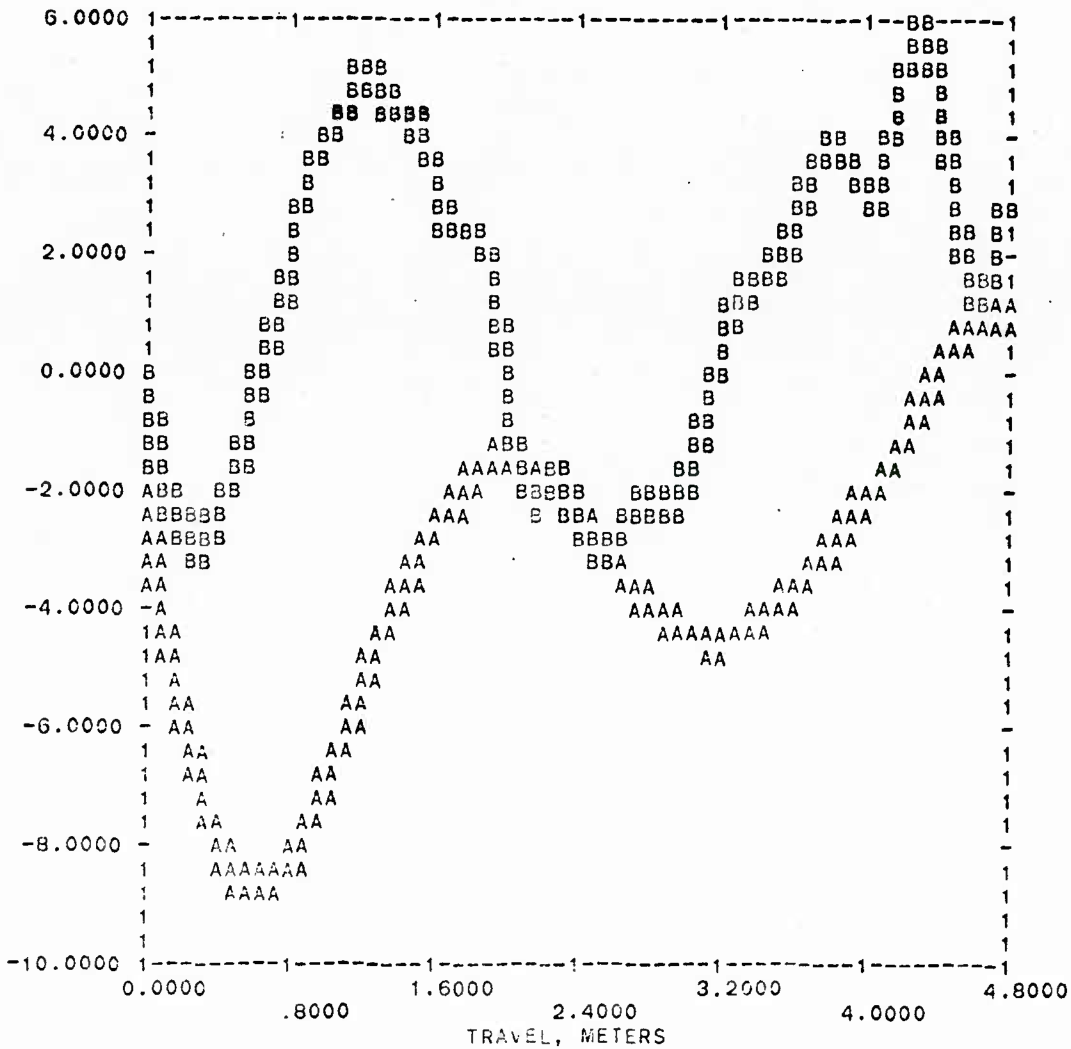


CURVE A = YAW ANGLE, B = YAW VELOCITY
SCALE OF VERTICAL AXIS-----
YAW ANGLE, MILLIRAD YAW VELOCITY, X 2 RAD/SEC

FIGURE 6 YAW ANGLE AND VELOCITY

EXAMPLE OF COMPUTATION OF PROGRAM BALLOT2

CG ECC=-.025MM,CG DIST=28.65CM, OBTR-BRT L=11.77CM
BORE DIAMETER = 12.024CM, BOURRELET D.= 11.976CM
FRICTION COEFF.= .040(OBTURATOR), .150(BOURRELET)
SPRING C.(MN/CM)=1.45(OBTURATOR), .49(BOURRELET)

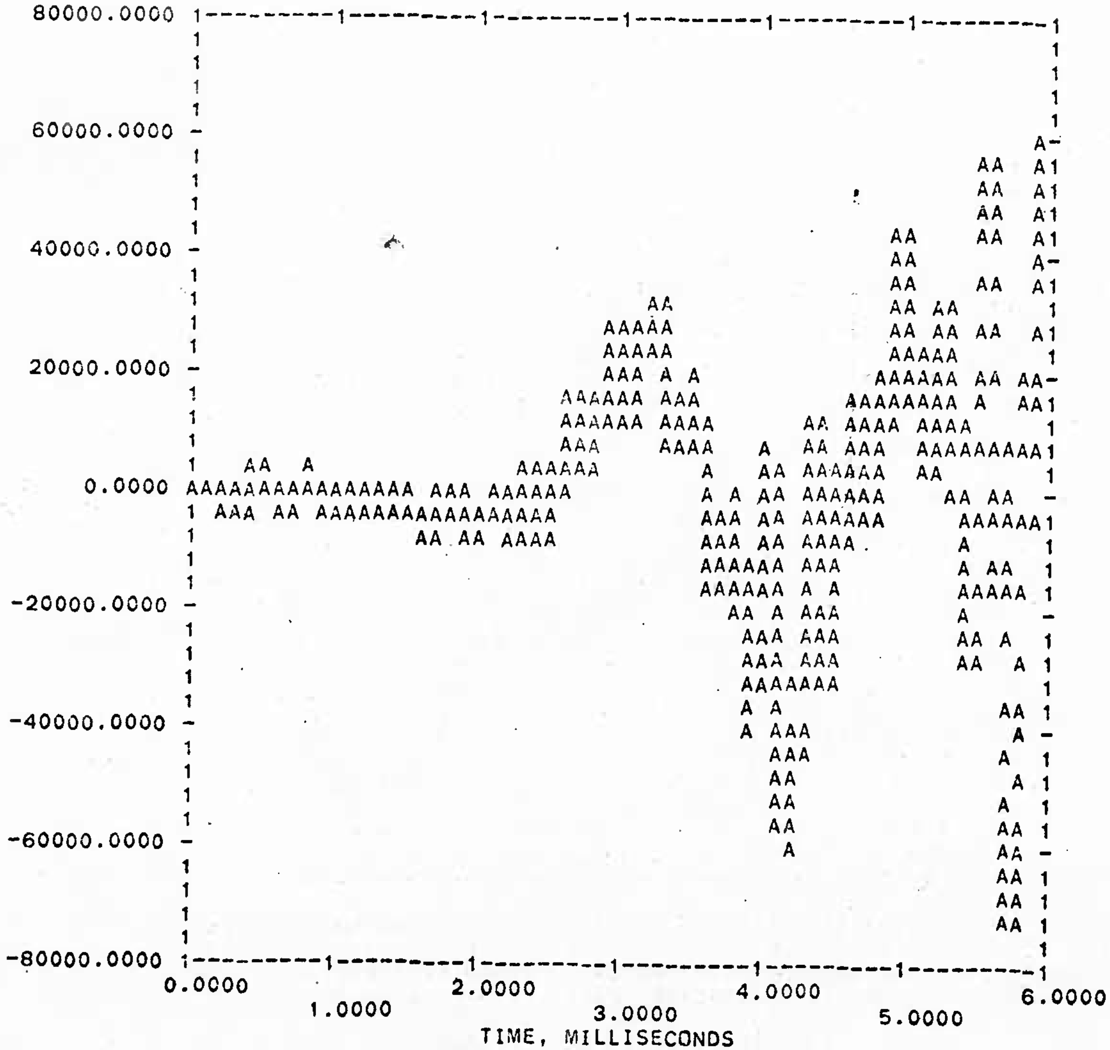


CURVE A = YAW ANGLE, B = YAW VELOCITY
SCALE OF VERTICAL AXIS-----
YAW ANGLE, MILLIRAD YAW VELOCITY, X 2 RAD/SEC

FIGURE 7 YAW ACCELERATION

EXAMPLE OF COMPUTATION OF PROGRAM BALLOT2

CG ECC=-.025MM,CG DIST=28.65CM, OBTR-BRT L=11.77CM
BORE DIAMETER = 12.024CM, BOURRELET D.= 11.976CM
FRICTION COEFF.= .040(OBTURATOR), .150(BOURRELET)
SPRING C.(MN/CM)=1.45(OBTURATOR), .49(BOURRELET)

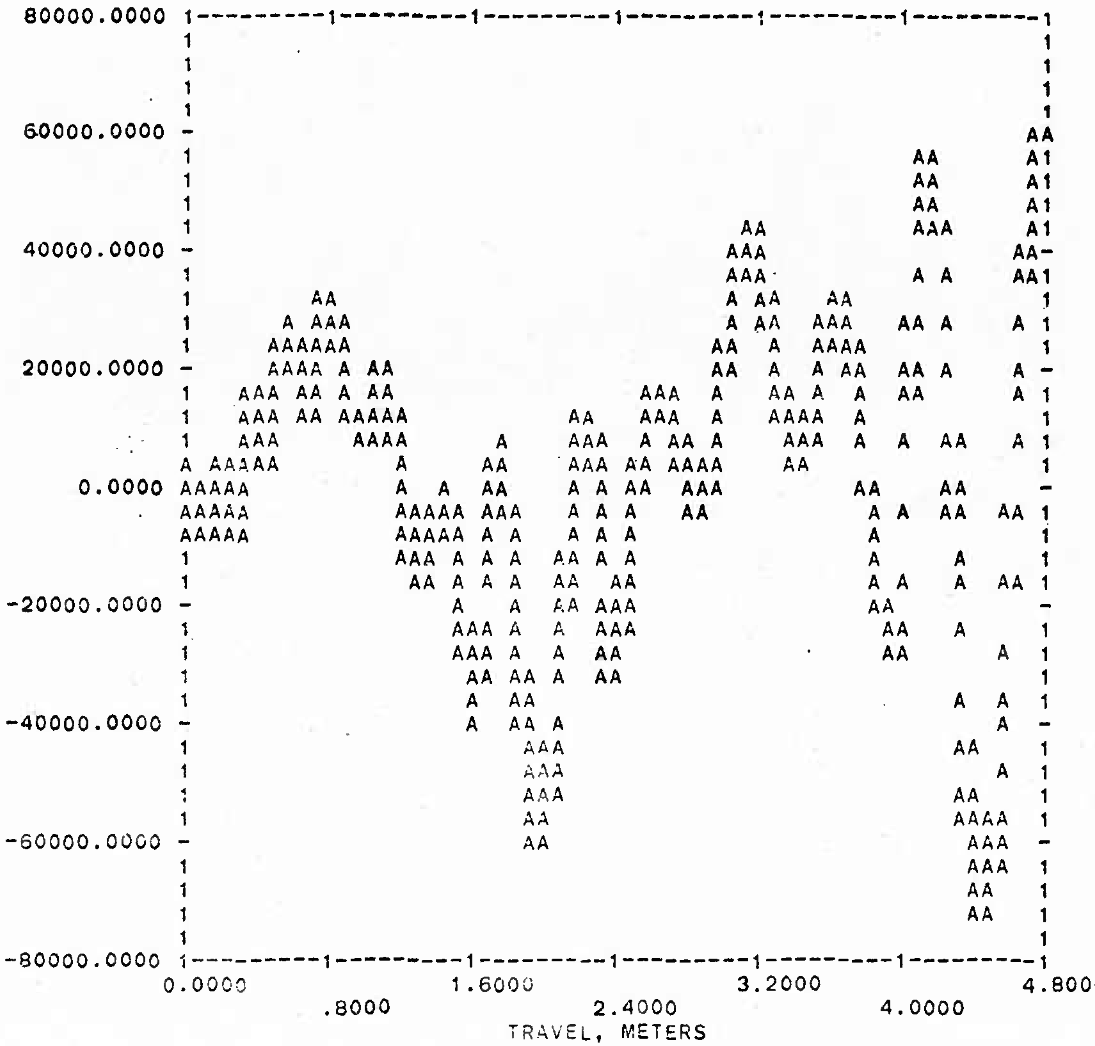


VERTICAL AXIS SCALE----- YAW ACCELERATION, RAD/SEC/SEC

FIGURE 8 YAW ACCELERATION

EXAMPLE OF COMPUTATION OF PROGRAM BALLOT2

CG ECC=-.025MM,CG DIST=28.65CM, OBTR-BRT L=11.77CM
BORE DIAMETER = 12.024CM, BOURRELET D.= 11.976CM
FRICTION COEFF.= .040(OBTURATOR), .150(BOURRELET)
SPRING C.(MN/CM)=1.45(OBTURATOR), .49(BOURRELET)

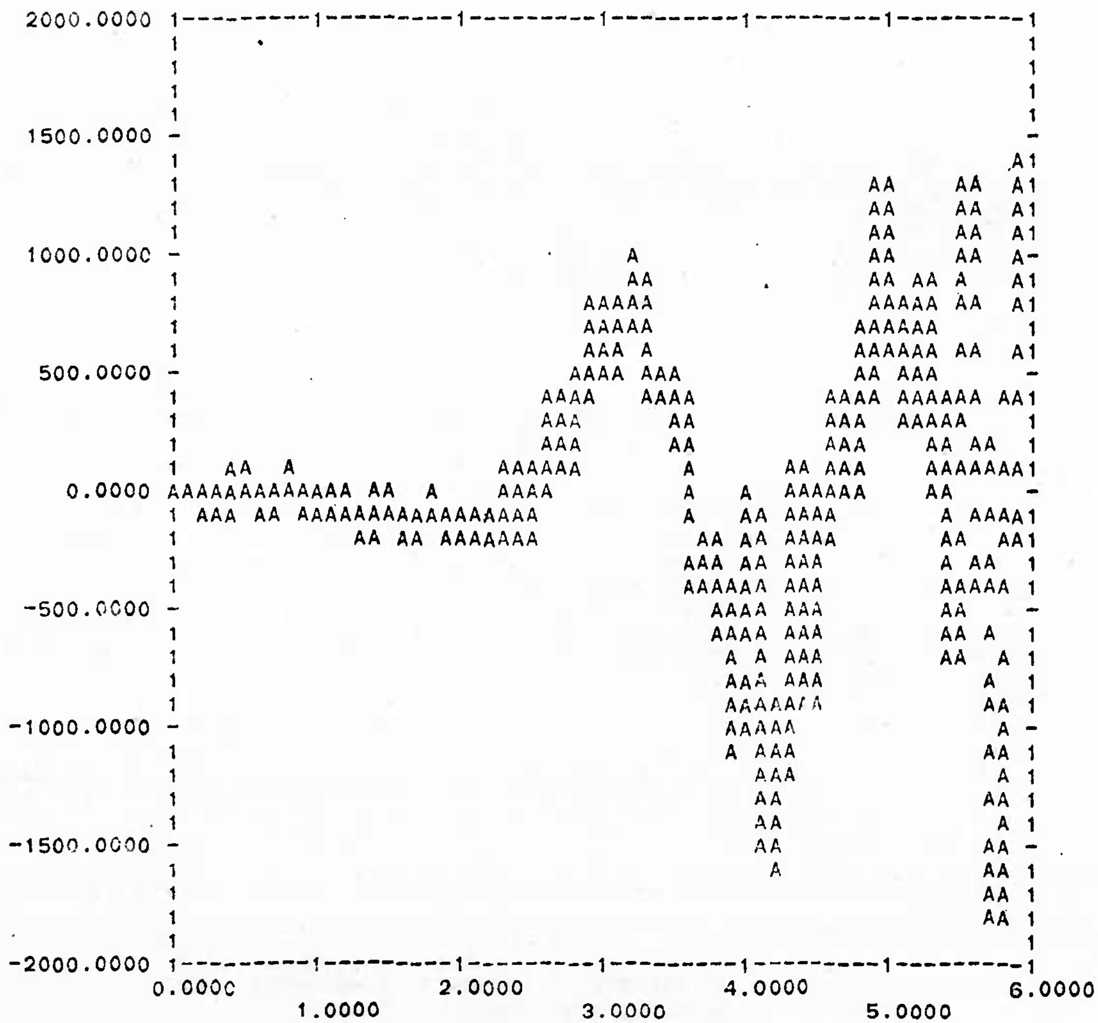


VERTICAL AXIS SCALE----- YAW ACCELERATION, RAD/SEC/SEC

FIGURE 9 NORMAL ACC. AT AXIAL POINT F

EXAMPLE OF COMPUTATION OF PROGRAM BALLOT2

CG ECC=-.025MM,CG DIST=28.65CM, OBTR-BRT L=11.77CM
BORE DIAMETER = 12.024CM, BOURRELET D.= 11.976CM
FRICTION COEFF.= .040(OBTURATOR), .150(BOURRELET)
SPRING C.(MN/CM)=1.45(OBTURATOR), .49(BOURRELET)



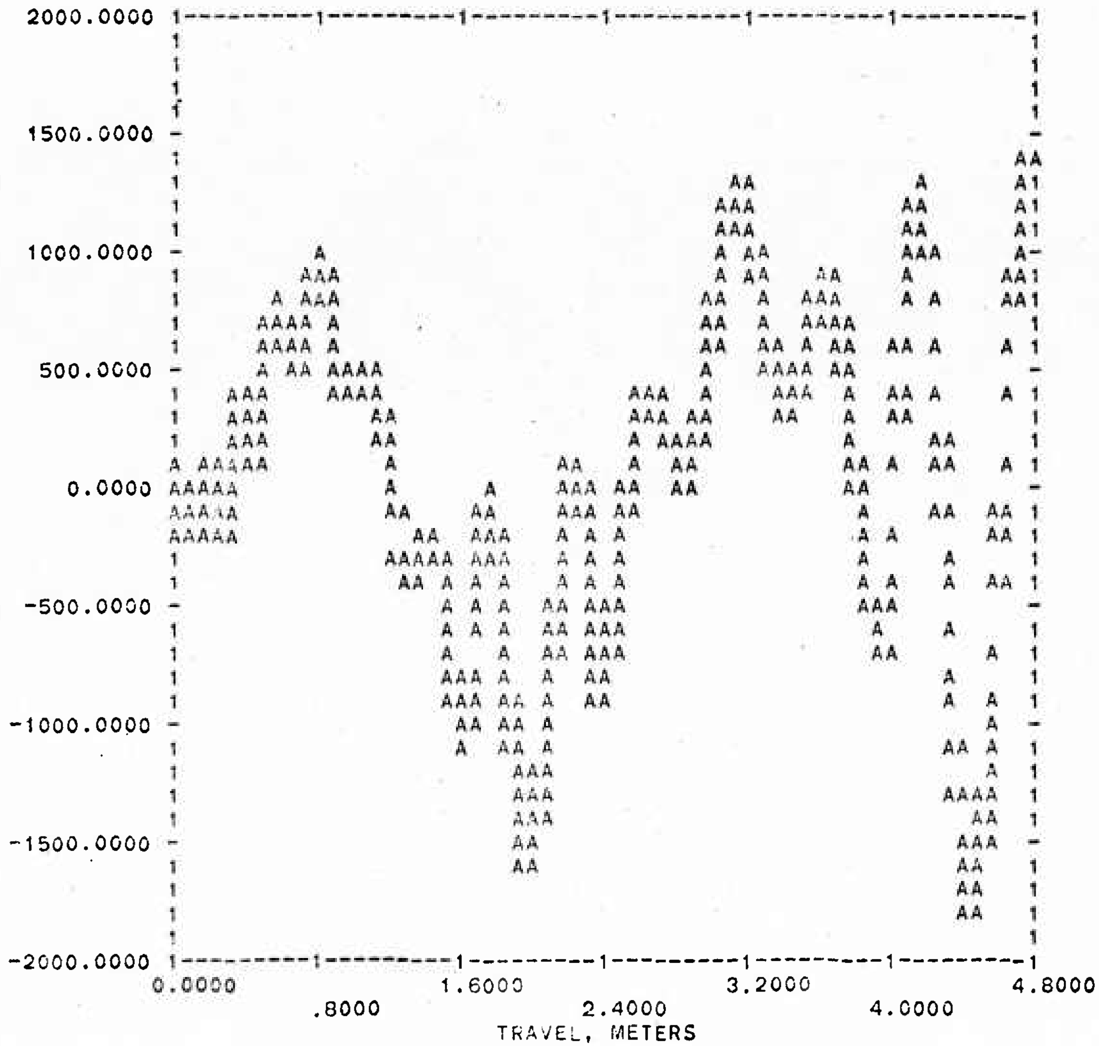
TIME, MILLISECONDS

VERTICAL AXIS SCALE----- ACCELERATION, GEE

FIGURE 10 NORMAL ACC. AT AXIAL POINT F

EXAMPLE OF COMPUTATION OF PROGRAM BALLOT2

CG ECC=-.025MM,CG DIST=28.65CM, OBTR-BRT L=11.77CM
BORE DIAMETER = 12.024CM, BOURRELET D.= 11.976CM
FRICTION COEFF.= .040(OBTURATOR), .150(BOURRELET)
SPRING C.(MN/CM)=1.45(OBTURATOR), .49(BOURRELET)

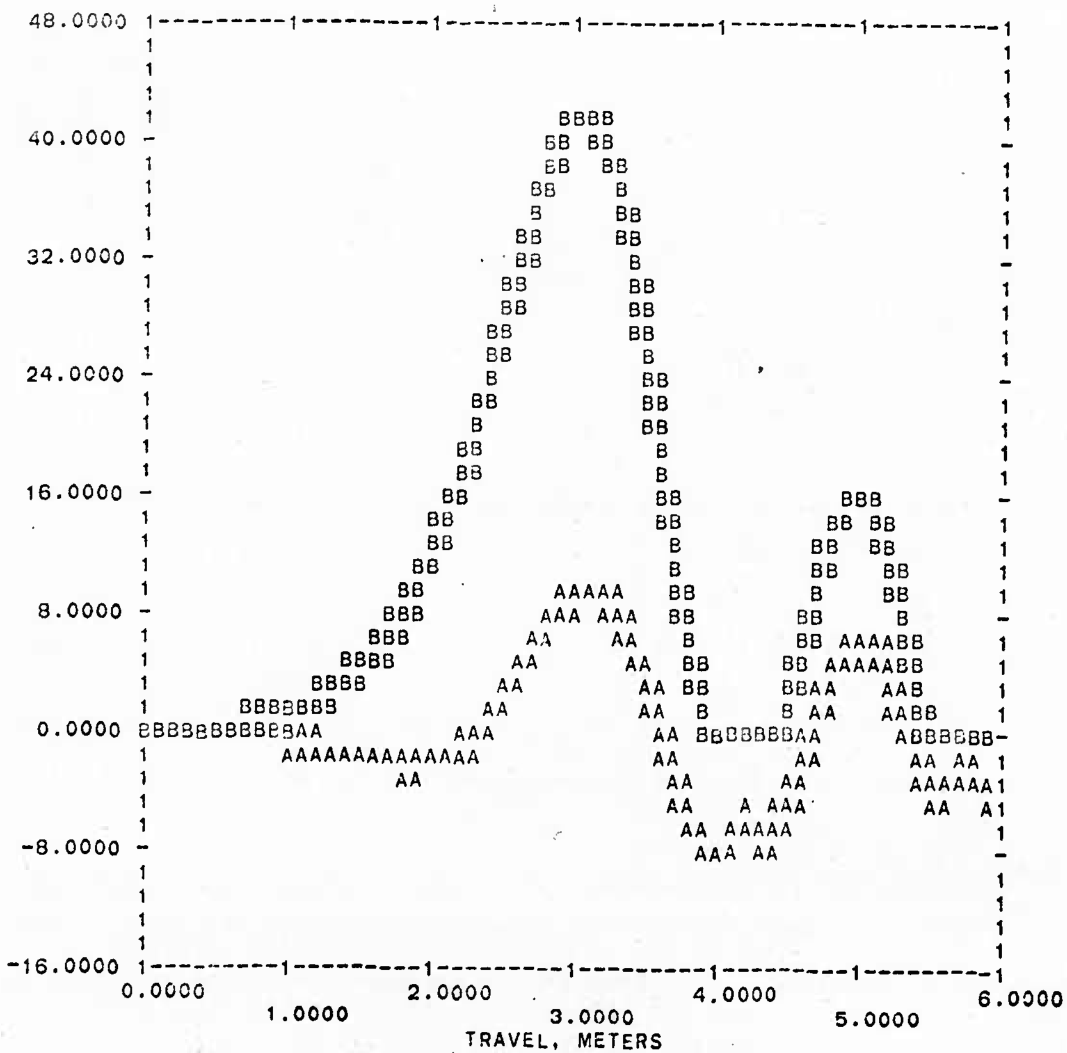


VERTICAL AXIS SCALE----- ACCELERATION, GEE

FIGURE 11 LATERAL FORCES

EXAMPLE OF COMPUTATION OF PROGRAM BALLOT2

CG ECC=-.025MM,CG DIST=28.65CM, OBTR-BRT L=11.77CM
BORE DIAMETER = 12.024CM, BOURRELET D.= 11.976CM
FRICTION COEFF.= .040(OBTURATOR), .150(BOURRELET)
SPRING C.(MN/CM)=1.45(OBTURATOR), .49(BOURRELET)

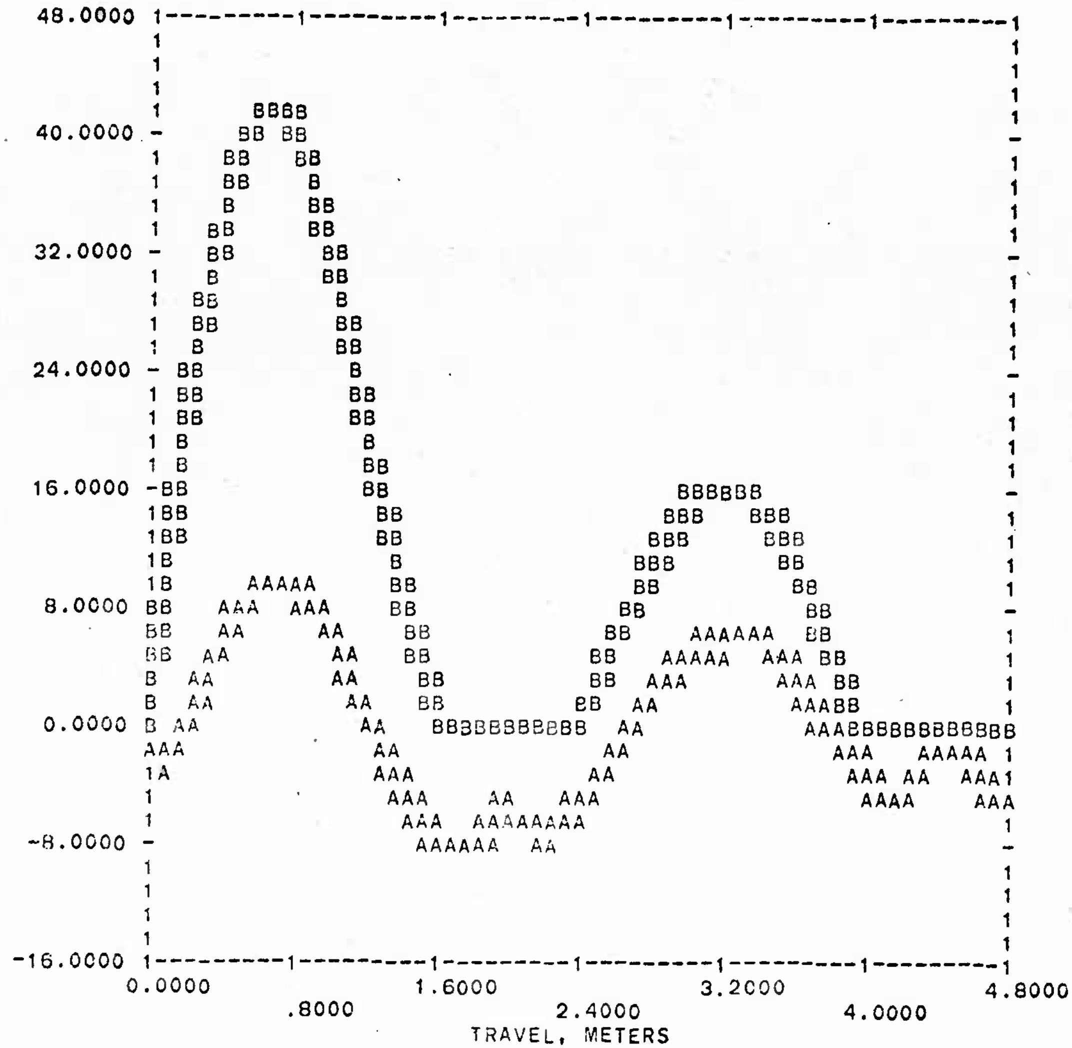


CURVE A = BAND FORCE, B = BOURRELET FORCE
VERTICAL AXIS SCALE----- FORCE, KILONEWTONS

FIGURE 12 LATERAL FORCES

EXAMPLE OF COMPUTATION OF PROGRAM BALLOT2

CG ECC=-.025MM, CG DIST=28.65CM, OBTR-BRT L=11.77CM
BORE DIAMETER = 12.024CM, BOURRELET D.= 11.976CM
FRICTION COEFF.= .040(OBTURATOR), .150(BOURRELET)
SPRING C.(MN/CM)=1.45(OBTURATOR), .49(BOURRELET)

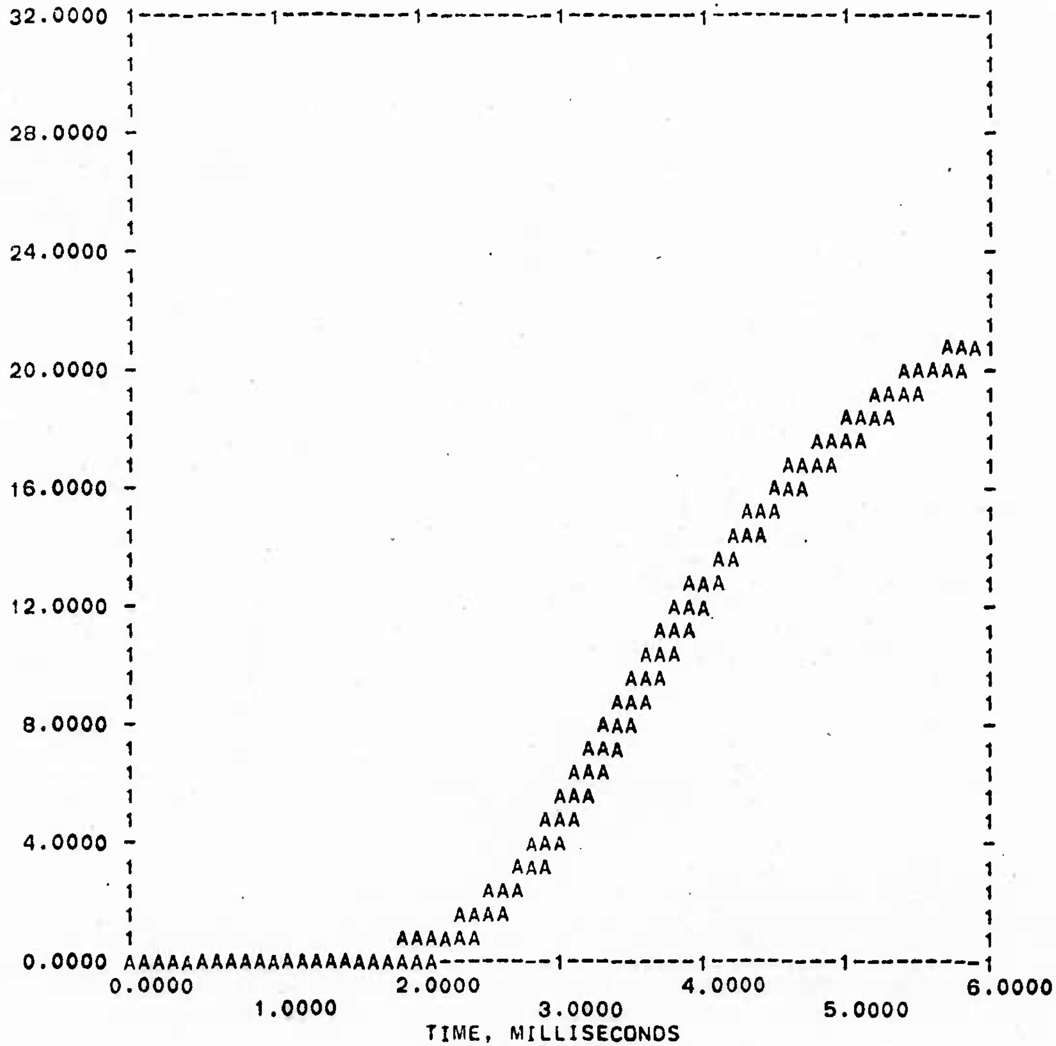


CURVE A = BAND FORCE, B = BOURRELET FORCE
VERTICAL AXIS SCALE----- FORCE, KILONEWTONS

FIGURE 13 AXIAL AIR RESISTANCE

EXAMPLE OF COMPUTATION OF PROGRAM BALLOT2

CG ECC=-.025MM,CG DIST=28.65CM, OBTR-BRT L=11.77CM
BORE DIAMETER = 12.024CM, BOURRELET D.= 11.976CM
FRICTION COEFF.= .040(OBTURATOR), .150(BOURRELET)
SPRING C.(MN/CM)=1.45(OBTURATOR), .49(BOURRELET)

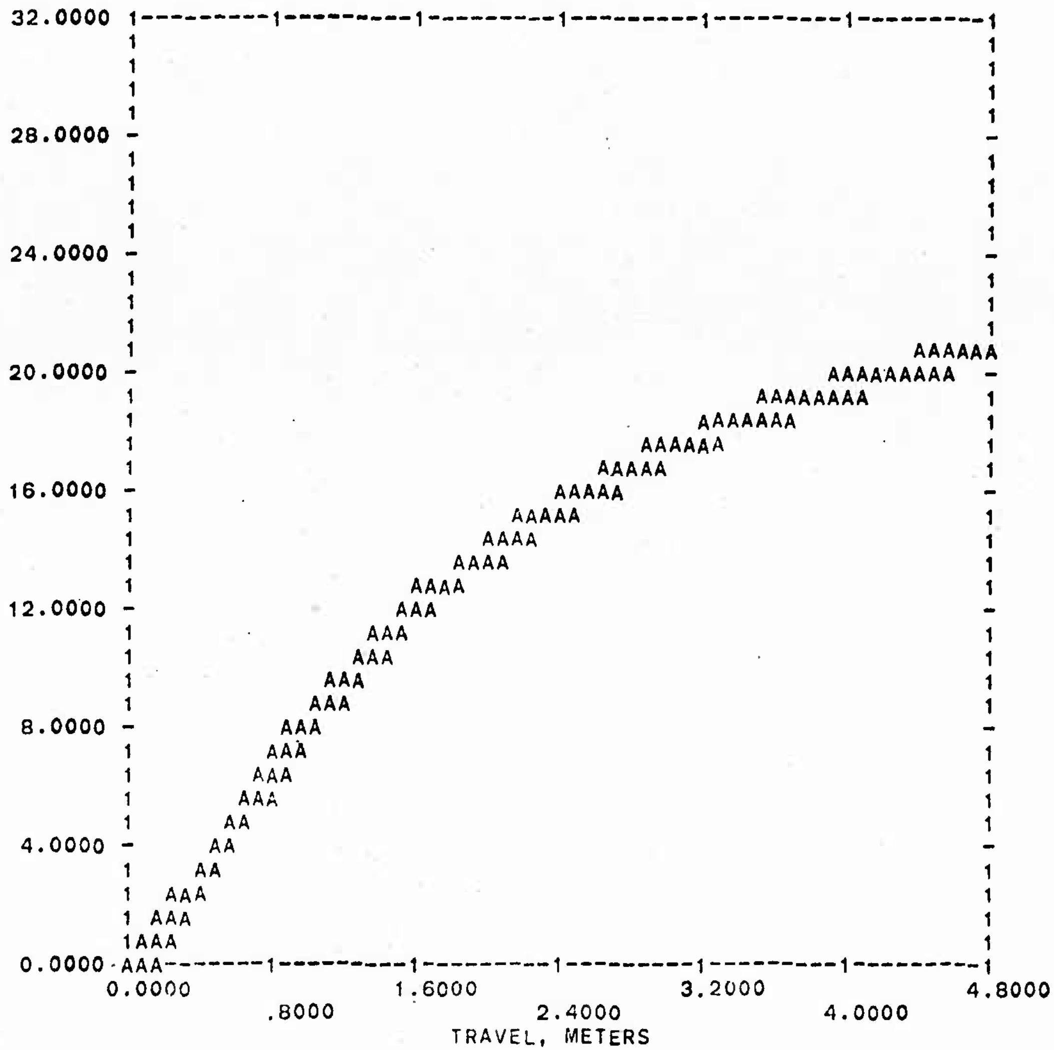


VERTICAL AXIS SCALE----- FORCE, KILONEWTONS

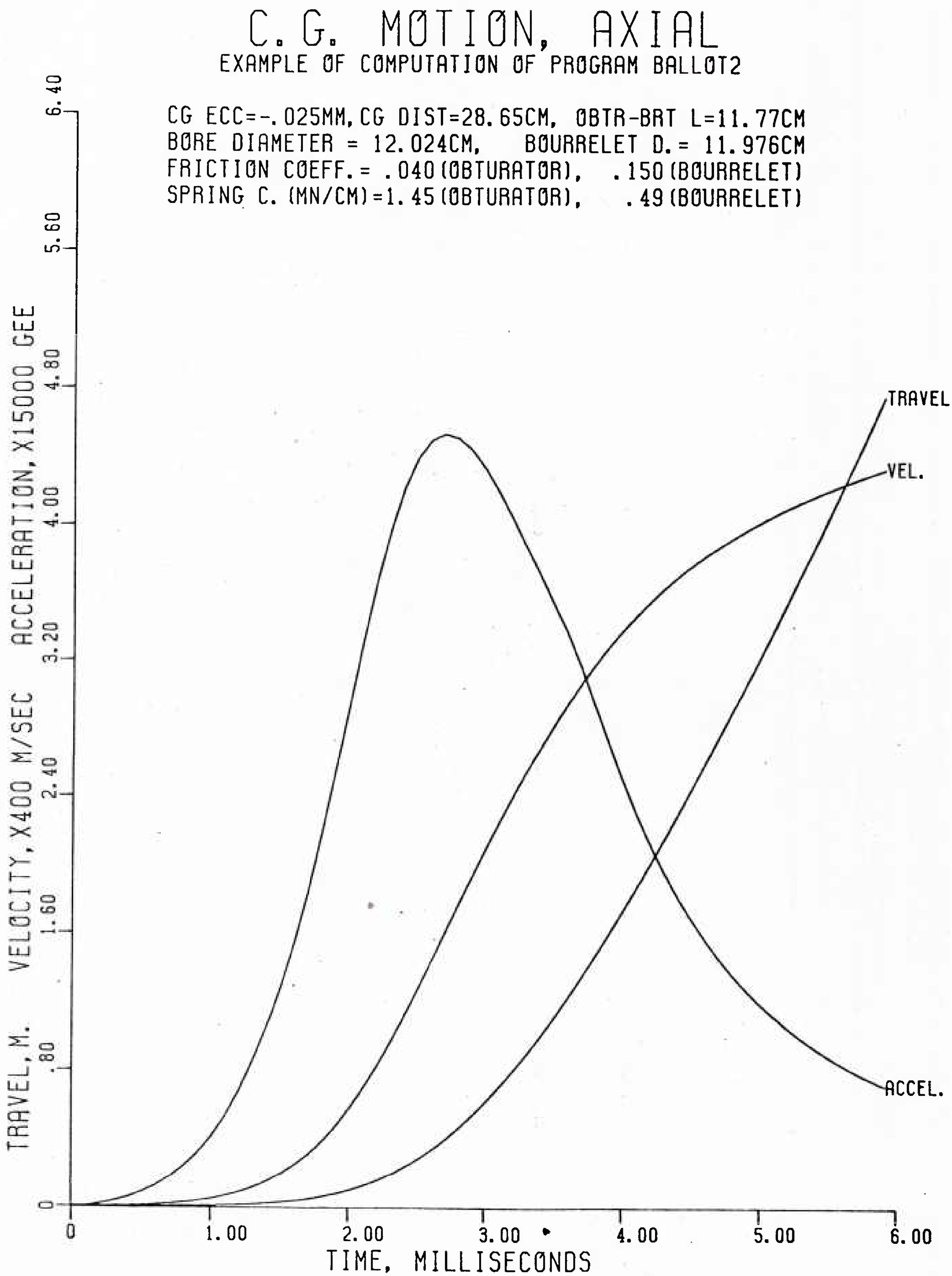
FIGURE 14 AXIAL AIR RESISTANCE

EXAMPLE OF COMPUTATION OF PROGRAM BALLOT2

CG ECC=-.025MM,CG DIST=28.65CM, OBTR-BRT L=11.77CM
BORE DIAMETER = 12.024CM, BOURRELET D.= 11.976CM
FRICTION COEFF.= .040(OBTURATOR), .150(BOURRELET)
SPRING C.(MN/CM)=1.45(OBTURATOR), .49(BOURRELET)

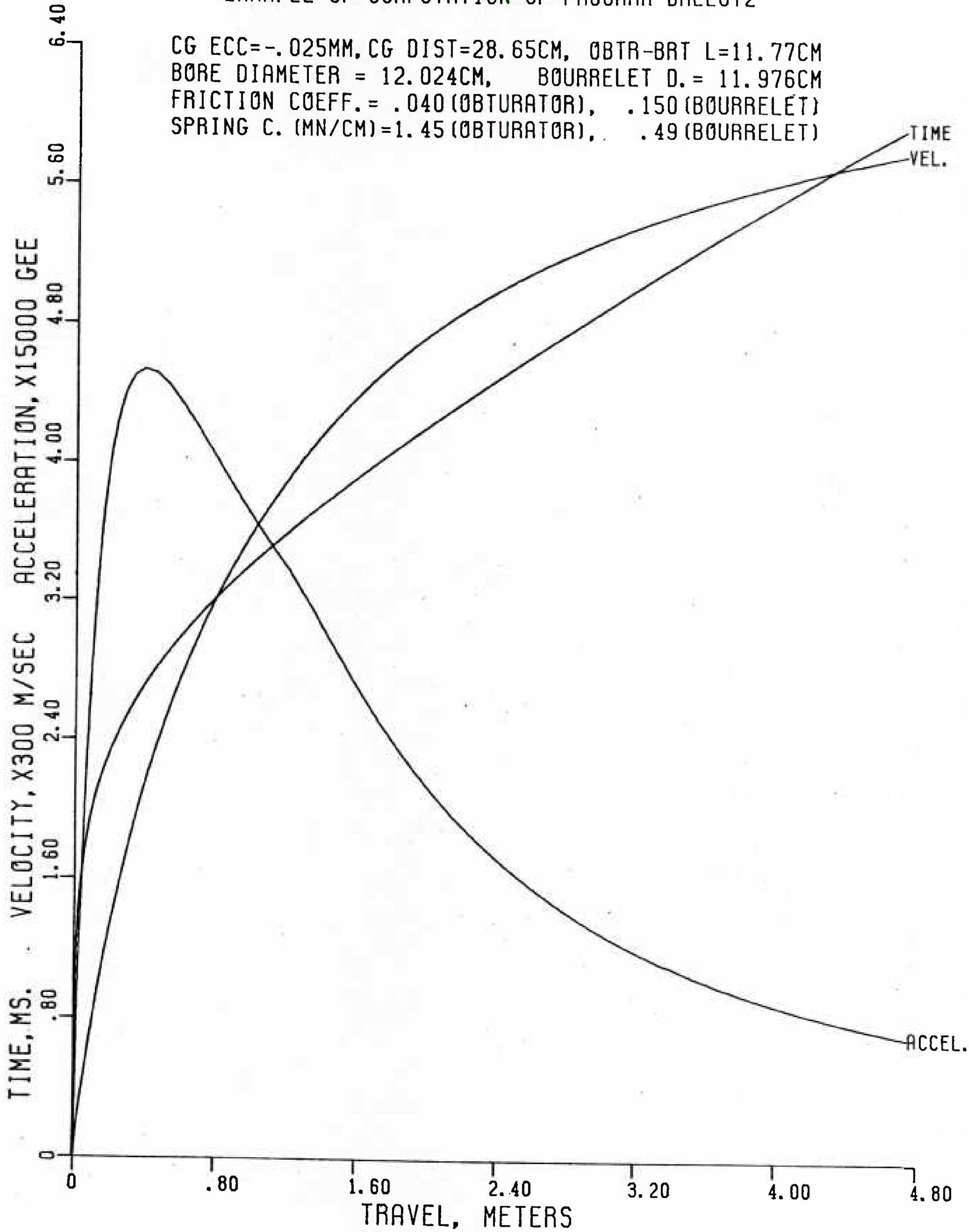


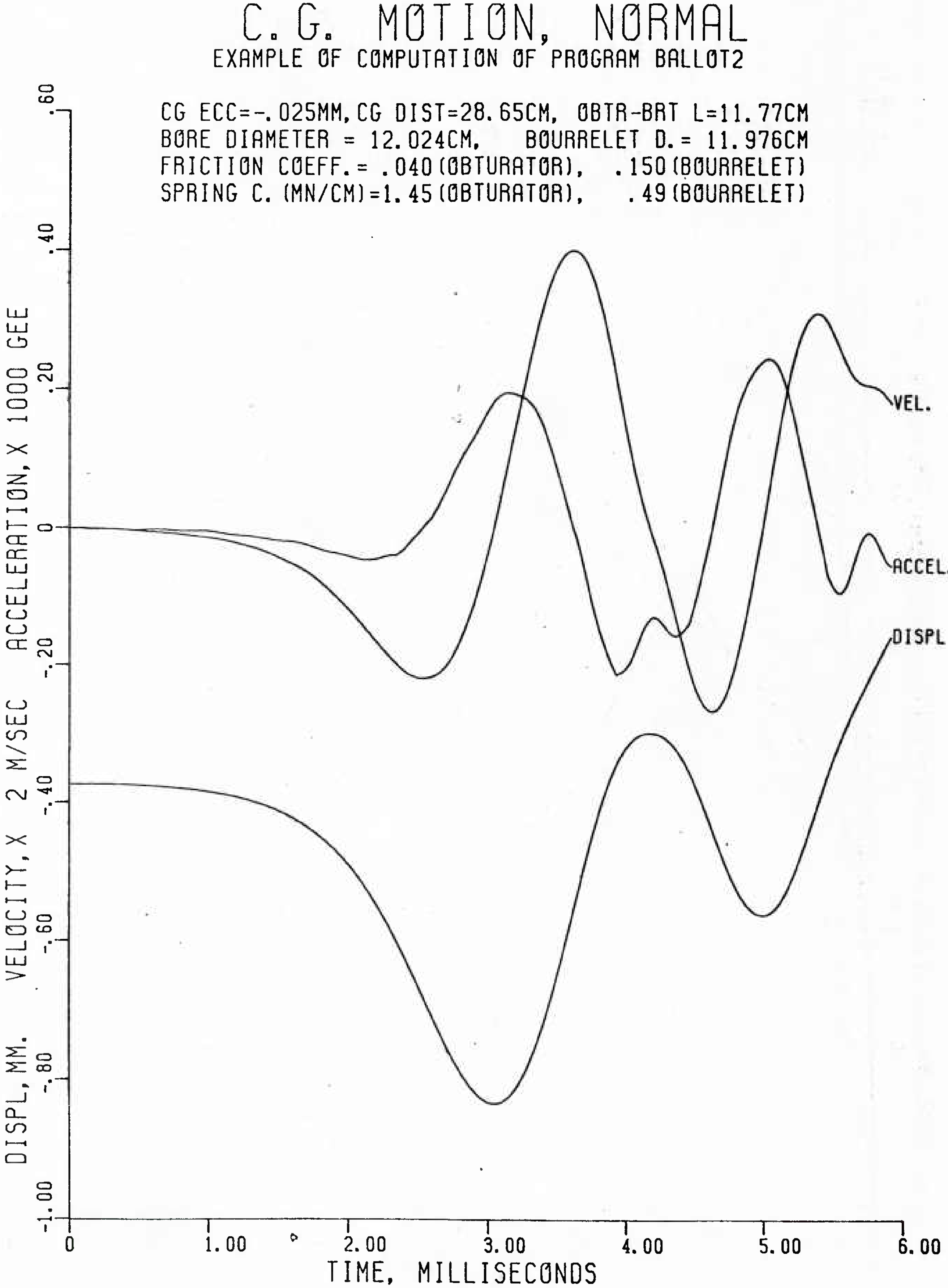
VERTICAL AXIS SCALE----- FORCE, KILONEWTONS

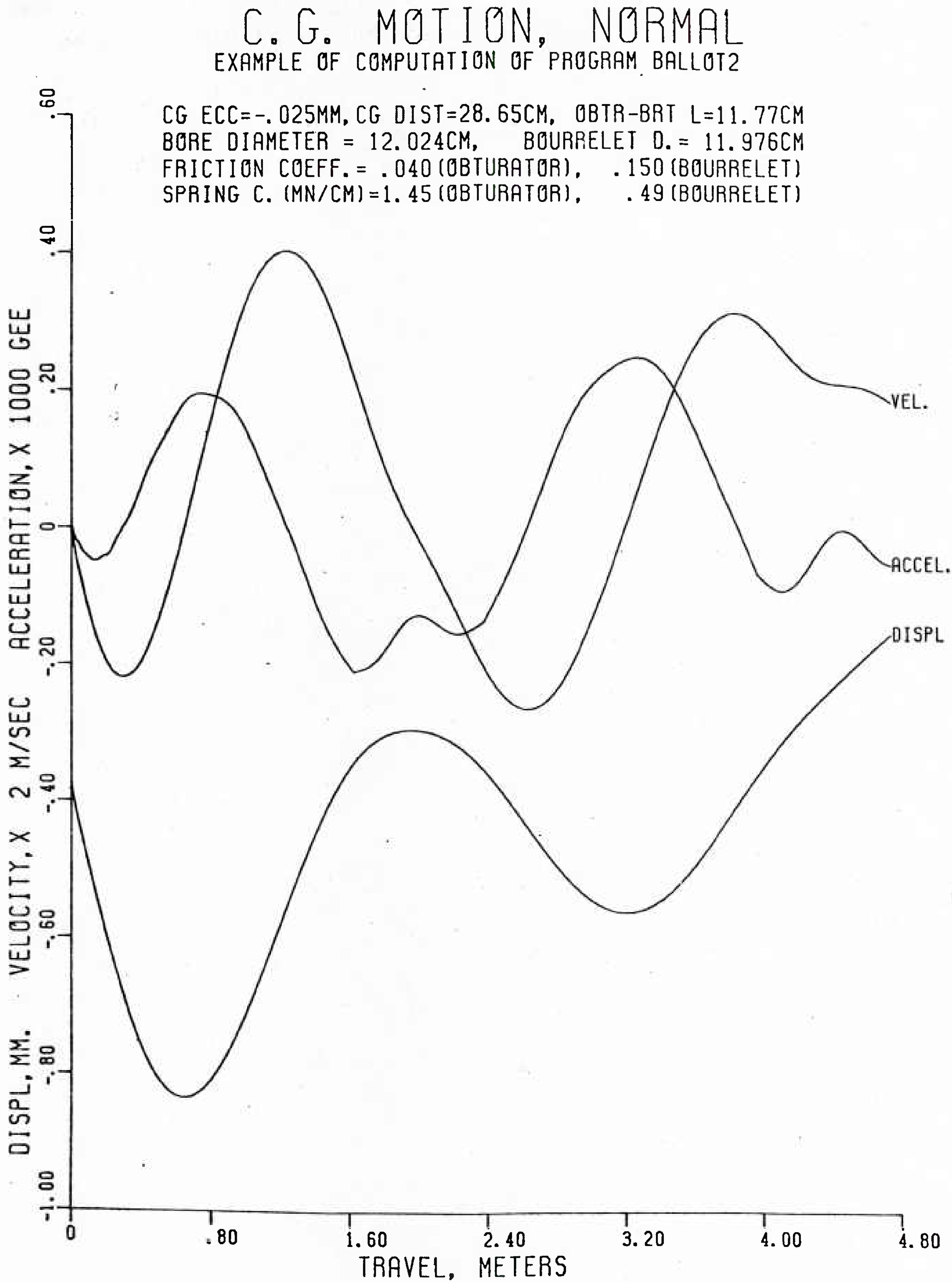

C. G. MØTIØN, AXIAL
EXAMPLE ØF COMPUTATIØN ØF PRØGRAM BALLØT2
CG ECC=-.025MM, CG DIST=28.65CM, ØBTR-BRT L=11.77CM
BØRE DIAMETER = 12.024CM, BØURRELET D. = 11.976CM
FRICTIØN CØEFF. = .040 (ØBTURATØR), .150 (BØURRELET)
SPRING C. (MN/CM) = 1.45 (ØBTURATØR), .49 (BØURRELET)
TRAVEL, M. VELØCITY, X400 M/SEC ACCELERATIØN, X15000 GEE
0
.80
1.60
2.40
3.20
4.00
4.80
5.60
6.40
TRAVEL
VEL.
ACCEL.
0
1.00
2.00
3.00
4.00
5.00
6.00
TIME, MILLISECØNDS

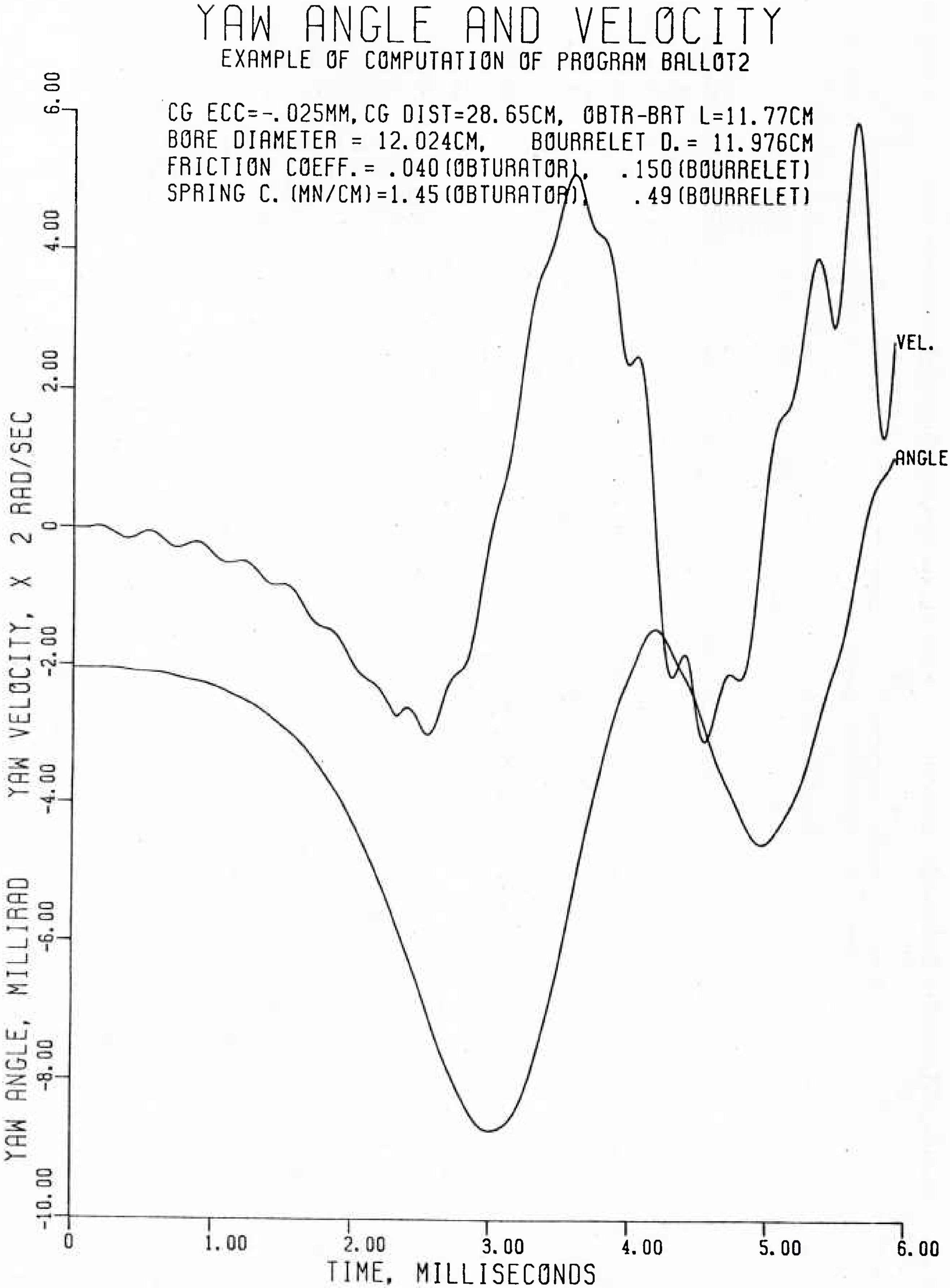
C. G. MOTION, AXIAL

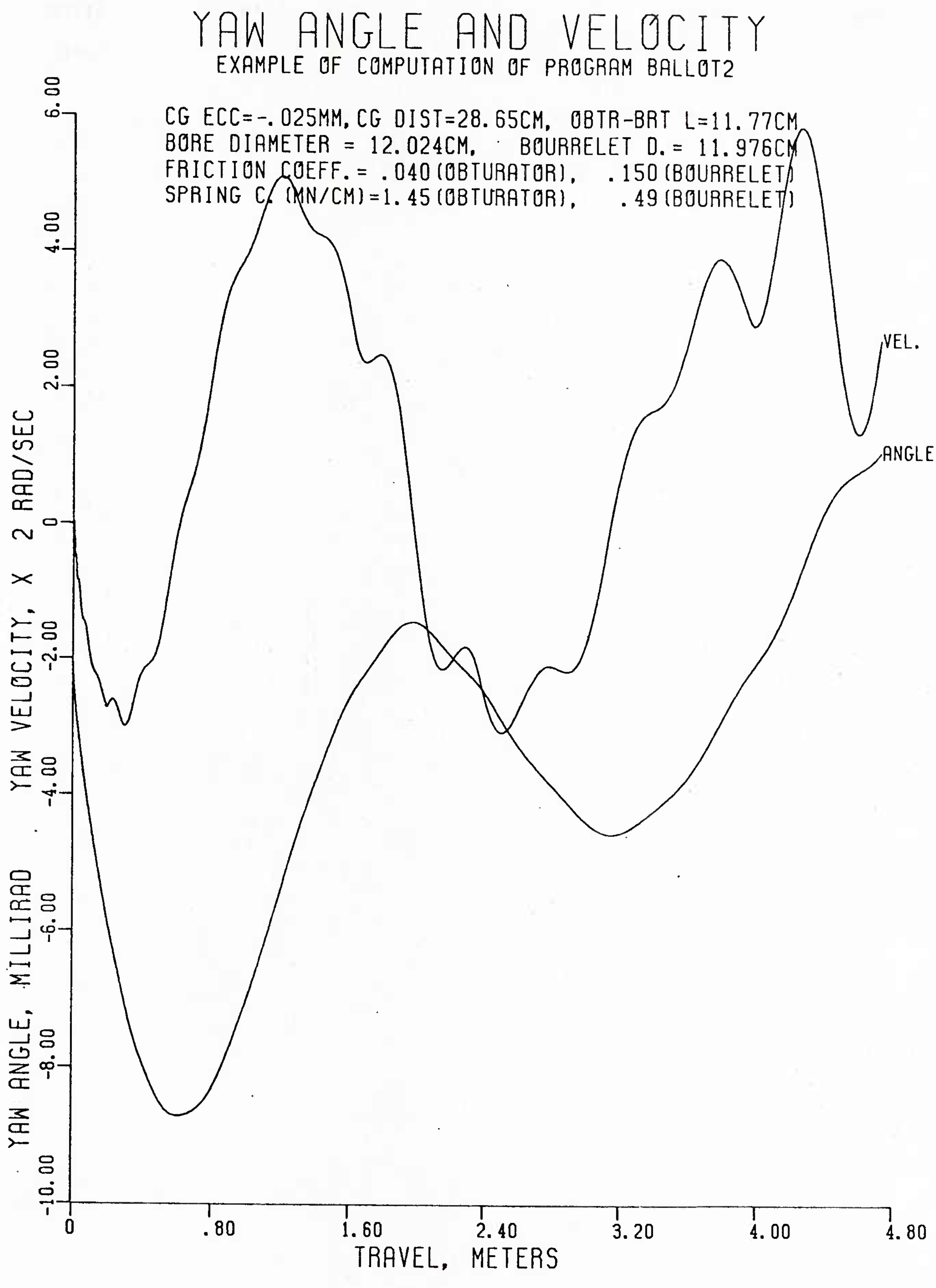
EXAMPLE OF COMPUTATION OF PROGRAM BALLOT2

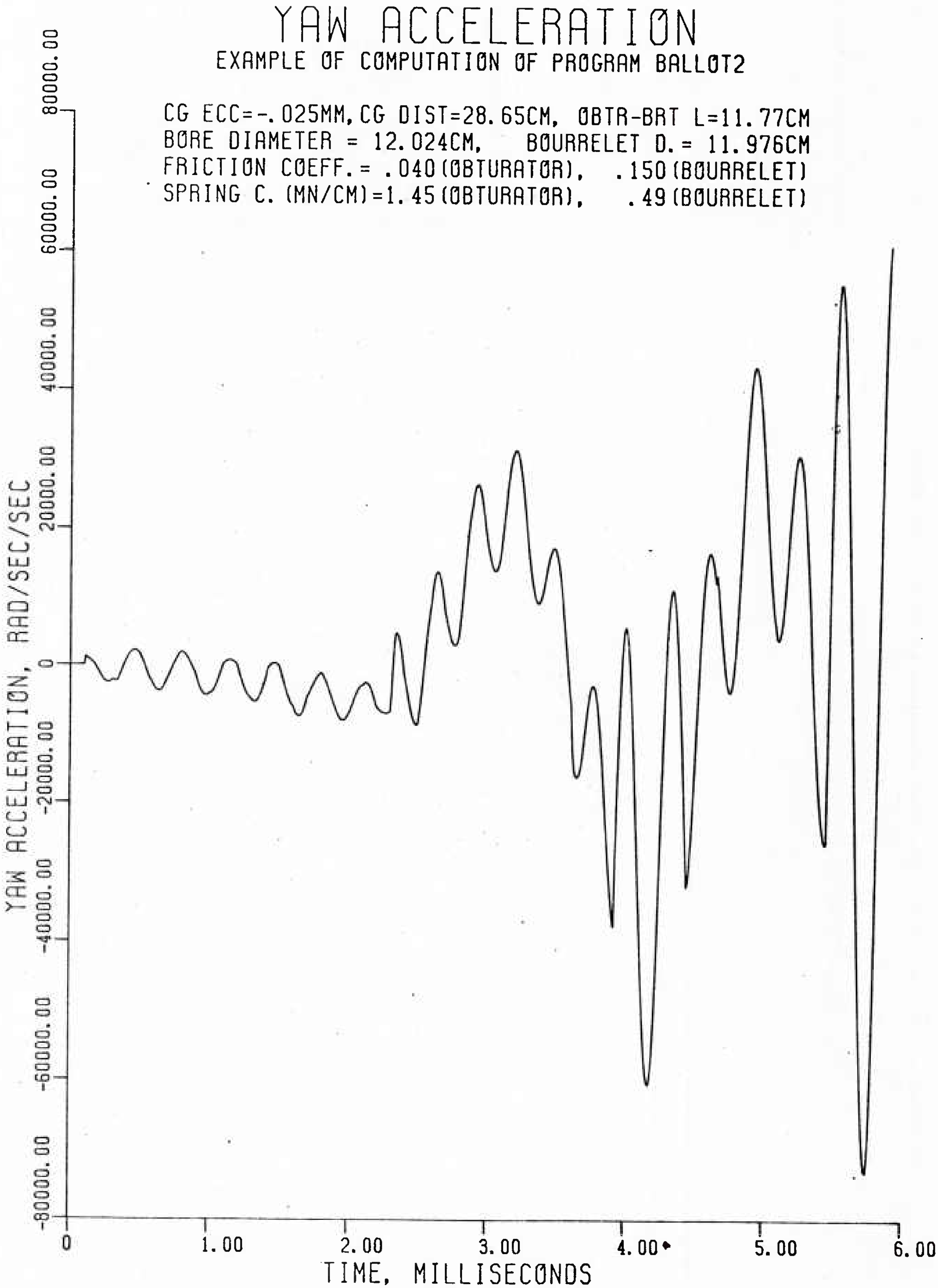



C.G. MØTIØN, NØRMAL
EXAMPLE ØF CØMPUTATIØN ØF PRØGRAM BALLØT2
CG ECC=-.025MM, CG DIST=28.65CM, ØBTR-BRT L=11.77CM
BØRE DIAMETER = 12.024CM, BØURRELET D.= 11.976CM
FRICTIØN CØEFF.= .040(ØBTURATØR), .150(BØURRELET)
SPRING C. (MN/CM)=1.45(ØBTURATØR), .49(BØURRELET)
VEL.
ACCEL.
DISPL
DISPL, MM. VELØCITY, X 2 M/SEC ACCELERATIØN, X 1000 GEE
.60
.40
.20
0
-.20
-.40
-.60
-.80
-1.00
0
1.00
2.00
3.00
4.00
5.00
6.00
TIME, MILLISECØNDS

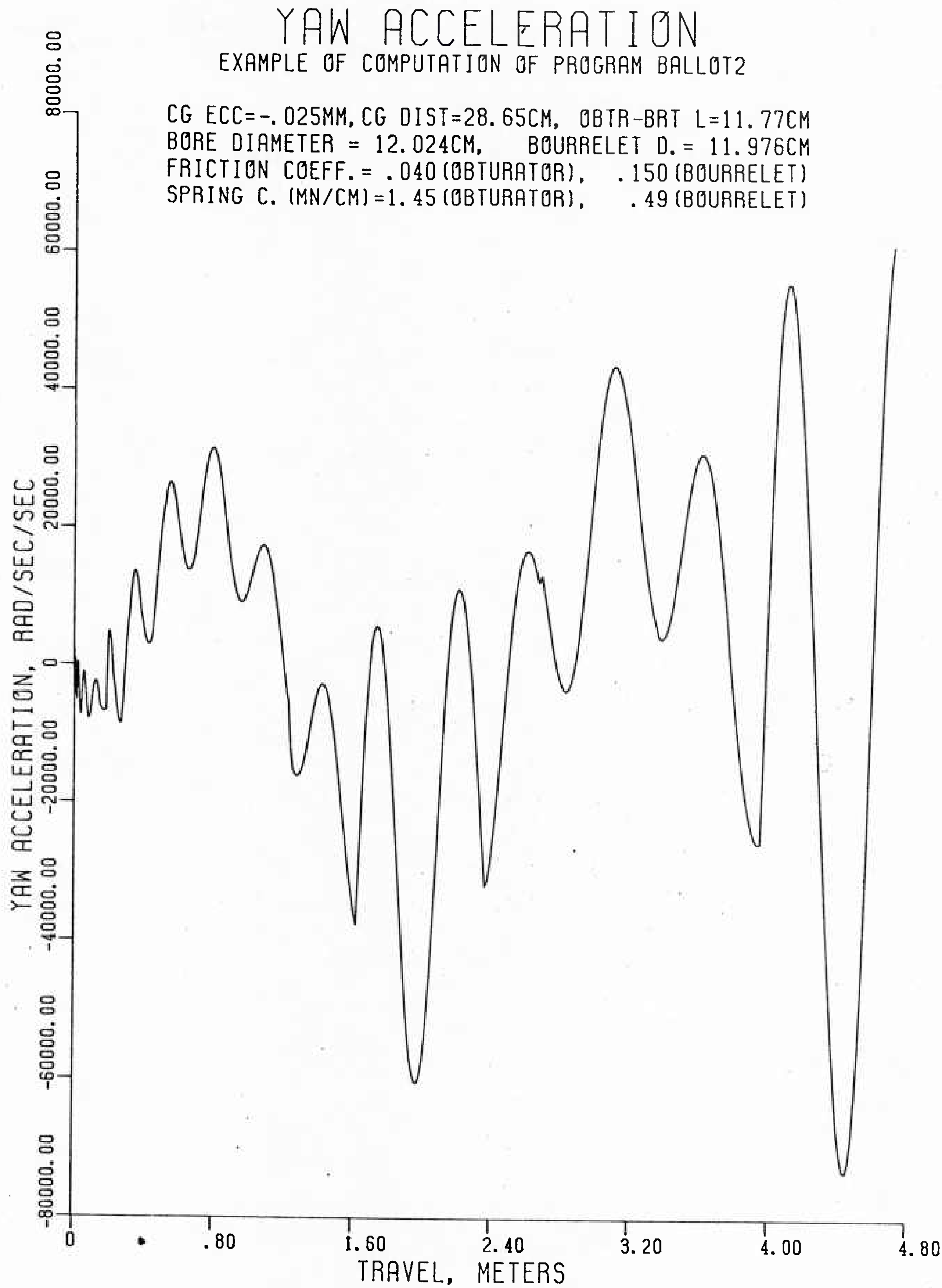

C. G. MØTIØN, NØRMAL
EXAMPLE ØF COMPUTATIØN ØF PRØGRAM BALLØT2
CG ECC=-.025MM, CG DIST=28.65CM, ØBTR-BRT L=11.77CM
BØRE DIAMETER = 12.024CM, BØURRELET D.= 11.976CM
FRICTIØN COEFF.= .040(ØBTURATØR), .150(BØURRELET)
SPRING C. (MN/CM)=1.45(ØBTURATØR), .49(BØURRELET)
DISPL, MM. VELØCITY, X 2 M/SEC ACCELERATIØN, X 1000 GEE
.60
.40
.20
0
-.20
-.40
-.60
-.80
-1.00
VEL.
ACCEL.
DISPL
0
.80
1.60
2.40
3.20
4.00
4.80
TRAVEL, METERS

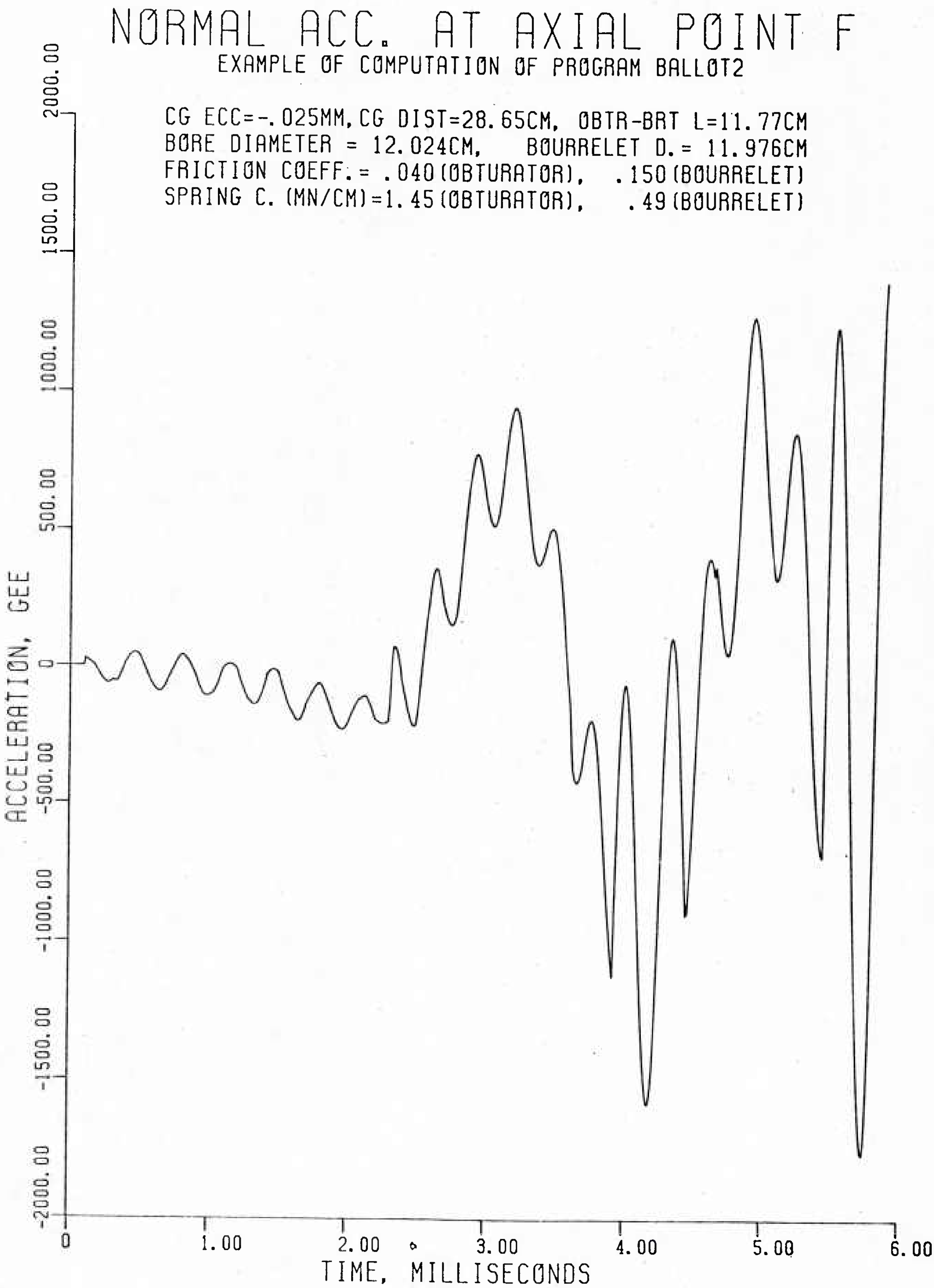

YAW ANGLE AND VELOCITY
EXAMPLE OF COMPUTATION OF PROGRAM BALLOT2
CG ECC=-.025MM, CG DIST=28.65CM, OBTR-BRT L=11.77CM
BORE DIAMETER = 12.024CM, BOURRELET D. = 11.976CM
FRICTION COEFF. = .040 (OBTURATOR), .150 (BOURRELET)
SPRING C. (MN/CM)=1.45 (OBTURATOR), .49 (BOURRELET)
VEL.
ANGLE
YAW ANGLE, MILLIRAD YAW VELOCITY, X 2 RAD/SEC
6.00
4.00
2.00
0
-2.00
-4.00
-6.00
-8.00
-10.00
0
1.00
2.00
3.00
4.00
5.00
6.00
TIME, MILLISECONDS

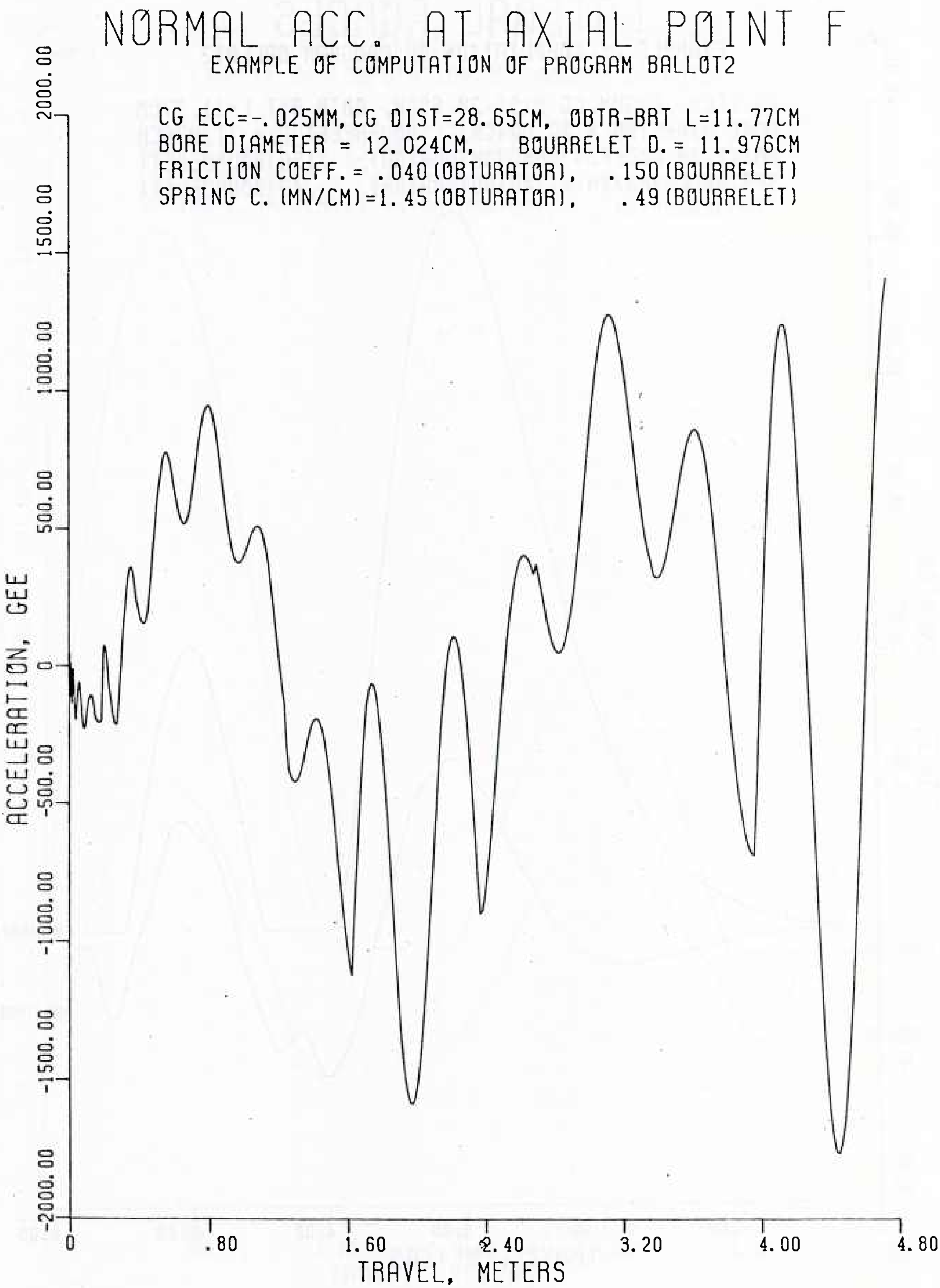

YAW ANGLE AND VELOCITY
EXAMPLE OF COMPUTATION OF PROGRAM BALLOT2
CG ECC=-.025MM, CG DIST=28.65CM, OBTR-BRT L=11.77CM
BORE DIAMETER = 12.024CM, BOURRELET D. = 11.976CM
FRICTION COEFF. = .040 (OBTURATOR), .150 (BOURRELET)
SPRING C. (MN/CM) = 1.45 (OBTURATOR), .49 (BOURRELET)
VEL.
ANGLE
YAW ANGLE, MILLIRAD YAW VELOCITY, X 2 RAD/SEC
6.00
4.00
2.00
0
-2.00
-4.00
-6.00
-8.00
-10.00
TRAVEL, METERS
0
.80
1.60
2.40
3.20
4.00
4.80



YAW ACCELERATION
EXAMPLE OF COMPUTATION OF PROGRAM BALLOT2
CG ECC=-.025MM, CG DIST=28.65CM, OBTR-BRT L=11.77CM
BORE DIAMETER = 12.024CM, BOURRELET D. = 11.976CM
FRICTION COEFF. = .040(OBTURATOR), .150(BOURRELET)
SPRING C. (MN/CM)=1.45(OBTURATOR), .49(BOURRELET)
YAW ACCELERATION, RAD/SEC/SEC
80000.00
60000.00
40000.00
20000.00
0
-20000.00
-40000.00
-60000.00
-80000.00
0
1.00
2.00
3.00
4.00
5.00
6.00
TIME, MILLISECONDS


YAW ACCELERATION
EXAMPLE OF COMPUTATION OF PROGRAM BALLOT2
CG ECC=-.025MM, CG DIST=28.65CM, OBTR-BRT L=11.77CM
BORE DIAMETER = 12.024CM, BOURRELET D. = 11.976CM
FRICTION COEFF. = .040 (OBTURATOR), .150 (BOURRELET)
SPRING C. (MN/CM)=1.45 (OBTURATOR), .49 (BOURRELET)
YAW ACCELERATION, RAD/SEC/SEC
80000.00
60000.00
40000.00
20000.00
0
-20000.00
-40000.00
-60000.00
-80000.00
0
.80
1.60
2.40
3.20
4.00
4.80
TRAVEL, METERS


NØRMAL ACC. AT AXIAL PØINT F
EXAMPLE ØF CØMPUTATIØN ØF PRØGRAM BALLØT2
CG ECC=-.025MM,CG DIST=28.65CM, ØBTR-BRT L=11.77CM
BØRE DIAMETER = 12.024CM, BØURRELET D.= 11.976CM
FRICTIØN CØEFF.= .040(ØBTURATØR), .150(BØURRELET)
SPRING C.(MN/CM)=1.45(ØBTURATØR), .49(BØURRELET)
ACCELERATIØN, GEE
2000.00
1500.00
1000.00
500.00
0
-500.00
-1000.00
-1500.00
-2000.00
0
1.00
2.00
3.00
4.00
5.00
6.00
TIME, MILLISECØNDS


NØRMAL ACC. AT AXIAL PØINT F
EXAMPLE ØF COMPUTATIØN ØF PRØGRAM BALLØT2
CG ECC=-.025MM, CG DIST=28.65CM, ØBTR-BRT L=11.77CM
BØRE DIAMETER = 12.024CM, BØURRELET D.= 11.976CM
FRICTIØN CØEFF.= .040(ØBTURATØR), .150(BØURRELET)
SPRING C. (MN/CM)=1.45(ØBTURATØR), .49(BØURRELET)
ACCELERATIØN, GEE
2000.00
1500.00
1000.00
500.00
0
-500.00
-1000.00
-1500.00
-2000.00
0
.80
1.60
2.40
3.20
4.00
4.80
TRAVEL, METERS

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